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Edited by N. N. Gurovskiy

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N. N. Gurovskiy

FOREWORD

The following essays are brought to the attention of the reader without pretending to offer a full explanation of all questions of the psychophysiology of the work of astronauts. This is explained first of all by the lack of sufficient factual material which will be accumulated with time on longer space flights and with the landing of man on other planets. /3

The result of investigations on the influence of various regimens of work and rest on man's capacity for work is presented in these essays with the aim of finding the greatest variance in length of day and rhythm of daily activity in space flight, and to establish objective laws of the adaptation of man to a daily cycle which may be imposed upon him by the conditions of future flight and life on other planets.

In the experiments, several properties of space flight have been simulated in order to study these regimens of work and rest, for instance sensory insufficiency and hypodynamia which make the process of adaptation of man to a new diurnal rhythm difficult, and elicit various disturbances of the physiological and psychological functions in his organism. In the works of several authors these disturbances have become an independent object of investigation. The selection of materials for these essays is in response to practical questions of space medicine in part dealing with the organization of the vital activity of crew members on a long orbital flight and interplanetary craft. It is for this reason that in the essays a great deal of attention is given to the problem of the regimens of work and rest for astronauts. The number of conditions involved in an extended space flight excludes the possibility of constructing a daily cycle for its participants based on a terrestrial 24-hour schedule. Among these conditions, of the greatest significance are the peculiarities of the professional activity of astronauts, which on the whole is that of an operator, as well as the character, intensity and rhythm of illumination on board the space vehicle and on other planets of the solar system. The demand for constant watch on board a space craft and the three or four hour limit on productive duration of this watch necessitate a shortening of the daily /4
cycle to 12-18 hours. As the experimental investigations show, adaptation to a new daily regimen sometimes takes an extremely long period of time and is accompanied by a lowering of the physical and mental capacity for work. This is why experimental investigations of the process of the adaptation to a new diurnal rhythm have especially real significance, and the recommendations which

follow from the data of these experiments can be used to organize and carry out prolonged space flights. Of no less importance is the problem of sensory insufficiency under the conditions of outer space. Weightlessness, the monotony of the professional activity, the monotony of the visually perceived surroundings during many stages of the space flight all give rise to a certain underloading of the system of human analyzers and, by the same token, to a lowering of the effective tonus of the higher section of his central nervous system. Such an underloading (sensory insufficiency) is accompanied by a lowering of the general psychological capacity for work and in certain individuals to a disturbance in the clarity of thought and to hallucinations. Recommendations for treatment of sensory insufficiency presuppose a careful investigation of all properties of this state.

On the whole, the essays have great interest to specialists in the field of organizing the work of crew members of space craft designed for various purposes.

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SEVERAL PECULARITIES IN WORK ACTIVITY OF ASTRONAUTS ON PROLONGED SPACE FLIGHT

N. N. Gurovskiy

ABSTRACT: The regimen of work defines the structure of life during a prolonged space flight. Specifications must be developed for the precise regulation of the work process of the astronauts. To accomplish this one can refer to scientific studies of the physiology and psychology of work, bearing in mind the unique conditions of space flight which have no parallel to life on Earth.

In space flight, the work is an extremely significant factor /5* which defines the structure of life. The characteristic property of the investigations of work regimens of various professions consists, as is well known, in that the objects of study are already existing types of human work activity. In addition, the work process is formed at the very beginning, and certain social and psychological inter-relationships between people in the work process are then formed; only after a certain length of time is the study of the peculiarities of this aspect of work begun and the influence of the regimen of work activity on the organism of the worker clarified.

On prolonged space flights, the life of the astronauts must be considered as a work process which must of necessity be regulated precisely. A new and extremely complicated task for space medicine is that of making recommendations for the rational structuring of the work of astronauts on prolonged space flights at a time when no such flights exist and naturally there is no work process.

In order to develop recommendations for the in-flight work regimen of astronauts, one must draw upon the experience of scientists which has been gathered by the study, and the work of various professional groups on the knowledge of general laws in the course of the psychological and physiological human process with careful analysis of the peculiarities and conditions of flight, as well as from data on the study of the organism's reactions in simulated activity of astronauts and laboratory experiment.

We shall not dwell upon an exposition of general laws and characteristics of human psychology nor upon the social side of labor. We

* Numbers in the margin indicate pagination in the foreign text.

will only try to present certain analyses of those conditions which appear to be characteristic for this work in prolonged space flights.

The life of a man on board a space ship essentially differs from the usual conditions of work in a number of ways. The most important of these can be formulated in the following manner. /6

(1) A prolonged stay under conditions of limited space on board a space ship is characterized by a dearth of changes in the external impressions that are characteristic of life on Earth. This condition permits one to speak about the poverty of external afferentation and of the monotony of stimuli.

(2) The change from the organism's usual rhythm of activity is characterized by little motion, by weightlessness, and by a lack of any real change in day and night.

(3) The impossibility of broad and diverse contacts with various people is a consequence of the seclusion and the unchanging nature of the ship's crew.

(4) The peculiarities of the microclimate, nourishment, and sanitary conditions, etc.

(5) The peculiarity of the psychological situation characterized by a feeling of remoteness from Earth, by the unusual circumstances, and by the possibility of serious emergency situations, etc.

It must be emphasized that for several of the above-mentioned pecularities of the life conditions of astronauts, one can find some sort of analogy in research into the physiology and psychology of labor. However, no experience exists for carrying out work operations under conditions of weightlessness in prolonged flight. This situation can very substantially change the performance of even the most ordinary work operation and calls for the creation of new work objectives. However, the formation of operational dynamic stereotypes is hardly possible; consequently, even the principles of training will proceed according to some new kinds of laws. Therefore, to contrast the work activity of the astronauts with known work processes does not follow.

The work activity of astronauts on a prolonged flight can be systematically divided into the following aspects.

(1) Activity at the time of duty watches at the control panel. This is the aspect of an astronaut's work that calls for the greatest degree of responsibility and includes the control of the operation of automatic systems and the observation of various indicators, instruments and signals.

This type of activity can be simply called a "monitoring" /7 activity, since it basically consists of monitoring the readings of instruments which demands virtually no motion whatsoever.

2 Activity in servicing life support systems. This will include the observation of apparatus responsible for maintenance of the necessary gas mixture in the air of the cabin, its humidity, temperature, sequences of illumination in the cabin and in other compartments the water supply system, etc., and also work in servicing these systems.

Thus, by their basic characteristics these aspects of the work in many respects will obviously fall together with the functions of checking the apparatus. Many instruments, obviously, will be situated on the central control panel. However, included with the activity of servicing the life support systems will be such work as the growing of higher and lower planets and repair work on apparatus that is broken down, that is, activity demanding definite and sufficiently varied motor activity on the part of a man. Moreover, such activities will be of the nature of constant work throughout the course of the flight (work with plants), and consequently they can be regulated; moreover periodic and unexpected work which is hard to take into account (repair work) will take place.

(3) Activity aimed at serving personal needs. Here one must consider work necessary for the preparation of food, performance of hygienic procedures and maintenance of sanitary conditions in he compartment, etc. This activity is also foreseeable and demands motor activity on the part of the astronauts, and it will be present as a constant factor occupying a sufficiently large portion of time among the other work activities.

(4) The activity of astronauts connected with the fulfillment of in-flight scientific observations will, by its very nature, be extremely varied and may even demand significant motor activity on the part of the astronauts throughout the entire flight, except for certain parts of it, and especially during EVA and disembarking onto other planets. At the present time it is difficult to give a sufficiently complete and detailed analysis and full characterization of the enumerated aspects of an astronaut's work activity. /8
During space flights on ships of the Vostok type, the astronauts carried out observations on the operation of automatic systems, performed manual operations in attitude control system of the ship, and took care of the life support systems.

It is obviously possible to distinguish two types of astronaut monitoring activity. The first type is the observation of instruments under normal conditions of operation of the automatic systems--an activity in which the intensity of work is not great. The second aspect--work carried out under conditions demanding especially active forms of observation involving a large number of signals and a rapid rate of appearance thereof (during attitude control, during docking of space craft at the time of landing, in emergencies, etc.).

Moreover, pure observation of instruments and signals takes place simultaneously with motor operations for the direction of the ship or of its systems.

The properties of the first type of activity are dictated by the necessity of monitoring instruments, the surveying of which is accomplished by way of an approved system of alternating and simultaneous observations of various aspects of signal types. In addition a sufficient level of perceptual activity and attention strain are combined with a lack of intensive muscular activity, which defines this activity as work operations taking place with little external effect. However in addition to this, astronauts must be in a constant state of operational preparedness in order to perceive any unforeseen changes in the makeup of signals should an emergency situation arise.

Such a combination of a standard well-mastered procedure for the monitoring of the usual instruments with the necessity of being in a state of constant preparedness for unforeseen changes in this procedure places a stress on the excitation and retardation processes of the cerebral cortex and, at the same time, places fairly high demands on the nervous system of the astronauts. Still greater demands are made during an activity period of the second type, when intensive instrument monitorings are combined with deciphering incoming signals, decision-making, and manual control of several operations. The swift tempo of such activity often demands /9 on the part of the astronaut a marshalling of all his resources, so that in the cerebral cortex situations of simultaneous existence of intensive excitatory and inhibitory processes can arise which, as is well known, can lead to conflicting interaction thereof.

It must be pointed out that the peculiarities of the monitoring activity of an astronaut's work at the control panel are dictated by specific automation features of the given spacecraft. However, this aspect of activity by its general structure most resembles that of an operator of highly automated systems. Moreover, the more intense forms of this work will take place very infrequently with the inclusion of some kind of special signals,(upon leaving the system of automatic apparatus during manuevers in the course of flight, etc.). In other words, the astronaut must constantly be in a state of preparedness for extreme activity. Such an aspect of work does not demand any muscular exertion and is characterized by little motion, by high activity of the visual and other analysors†, and by the stress of attention. Moreover, a limited sphere

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† Translator's note: An analysor is defined as "a neural apparatus which begins at the periphery as a sense organ or as a sensory nerve ending connected by means of a chain of neurons which centers in the lower and high segments of the central nervous system". Jablonski, Stanley: Russian-English Medical Dictionary. Ben S. Levine Ed., Academic Press, New York, 1958, p. 14.

of associations instilled with the aid of the signalization system is used, and no development of new and complex reflexes and differentiations constituting the physiological expression of the creative function of the brain takes place. This aspect of work activity is connected chiefly with the processes of perception and with the analysis of information on the basis of already developed stereotypes.

That which was asserted previously regarding the peculiarities of the monitoring activity of the astronauts while working at the control panel when all instruments and systems work normally must be emphasized once more. On the whole, it is difficult to overestimate the significance of the human creative activity during a space flight in making observations, rationalizing all phenomena, making decisions, accomplishing a series of jobs etc.. The physsiology and psychology of monitoring-type activity has been developed less than that of physical labor. The characteristics of such activity pertaining to space flight are as follows: /10

- The monitoring of instruments under conditions of intense perceptual activity and attention strain does not necessarily produce any significant muscular activities;

- The presence of general tension and stress connected with the possibility of the appearance of an emergency situation.

However, calculations of the probability of serious emergency situations arising show that there is an insignificant possibility of such emergencies in space flight. Consequently, the activity of astronauts on watch at the control panel is basically connected with monitoring in the pure sense.

It has already been noted that the work of the astronauts under special conditions (when the docking of two ships takes place at the time of landing or when maneuvering the ship in the course of its flight) is an exception. However, these stages occupy a very insignificant period in the usual duration of prolonged space flight, and the peculiarities of the work during this period have a significant number of analogs in aviation. Moreover, this activity on the part of the astronaut is accompanied by muscular exertions and sensory correction . At the basis of the monitoring activity by an astronaut lies the specific well-known problem of the observation of all indications of the instruments and signals distributed on the control panel, and the skill to carry out monitoring activities according to plan systematically and with maximum completeness.

The great responsibility and strain connected with this stimulates a rise in the tonus of the cortex. However, insofar as such a strained condition is difficult to maintain at a constant level, quite soon fatigue will develop and consequently a lowering of vigilance.

Thus, the peculiarities of the activity of an astronaut on watch are basically connected with the process of perception at a time of strained attention and the absence of any kind of external activity.

So in space flights, instrument display (signal) monitoring activity is limited only to observation and to an absence of motor activity. This is similar to activity with an inhibited "end". (Several functions with such an "end" are associated with signals appearing in the secondary signal system in the form of conclusions of the "all is normal" type). On the physiological level this signifies that the work process of an astronaut at the control panel is a process little correlated with feedback or sensory correction, /11
although it is absolutely necessary, the observation of instruments, the processes of perception, and interpretation of signals are reflex processes. The weak feedback support hinders their course.

The lack of results from preceding operations in the course of the monitoring function makes the work of the astronaut continue without the support of received effects. From this it follows that in order to make recommendations for the structuring of the astronauts' watches at the control panel, it is necessary to plan the work in such a way that it consists of separate stages having completeness in the form of distinct results.

Monitoring activity during the watch period evidently will be composed of homogeneous components. The lack of variety in switching between various types of work causes, as is well-known, a relatively quick development of fatigue, gives rise to a diminution of precision of perception and increases the possibility of errors.

All these peculiarities in the work of an astronaut monitoring automatic systems appear especially acute in circumstances where the automation of processes has reached such levels that information becomes relatively insignificant and the activity of the operator takes place under conditions of insufficient stimuli.

The question of such an insufficiency has not been illuminated broadly enough in the literature. Thus, for example, there are noteworthy data to the effect that the curtailment of the quantity and variety of signals has a more deleterious effect on a person than a surplus of them (certainly within given limits), because by this the working rhythm is lost, an inhibitory process arises and radiates and a feeling of boredom appears. This leads to the thought that the maximum automation of all systems carried out with the noble aim of the relief of the astronaut and of providing for the safety of flight may at the same time play a negative role. In this regard further experiments are necessary relating to specific systems of space flight apparatus.

Thus the work of astronauts while on watch at the control panel is a unique type of work, necessitating the conducting of experiments directed toward the lessening of its negative characteristics. In this respect, questions concerning the development of optimal regimens and of other measures for the organization of a given type of work occupy a primary role. /12

Briefly mentioning the other aspects of work performed by an astronaut during a space slight of extended duration (tending to personal needs, repair and adjustment work, etc.), i.e., those aspects which include as a necessary element a certain amount of motor activity. Their uniqueness is dictated by the specific freedom of movement under conditions of weightlessness and of the limited size of the cabin of the spacecraft.

Questions concerning the properties of the coordination of a man's motions must necessarily be considered as special problems to be examined by the analysis of work movements under conditions of unusual forms of foot and handholds. Moreover, it is important to study the processes of an organism's adaptation to the conditions of weightlessness.

Thus in standardizing an astronauts' work, great attention must be paid to the study of the influence of space flight conditions on this work. It is possible to blame its harmful effect on the general status of the astronaut's organism and, in particular, on the status of his higher nervous activity.

According to the data of some investigators, the restricted space and the lack of sensory stimuli create psychological tension and fatigue -according to the data of others, the development of extreme forms of inhibition. Therefore, it is necessary to examine in detail the influence of a factor such as the invariability and monotony of environment on human work processes.

The works of a number of scholars have indicated the important role played by the change of sensory stimuli in man's life and work. I.I. Pavlov showed that monotony leads to the development of diffuse forms of inhibition in the cerebral cortex. A significant number of investigations have shown the deleterious influence of monotonous forms of work on a man.

The organization of human work activity on Earth allows for the possibility of his switching between different forms of work, and of changing the stereotyped situation which accompanies work activity.

Under the conditions of prolonged space flight, it is difficult to change the stereotyped monotonous circumstances of work and life. For example, during a flight to Mars lasting around three /13 years, a small number of people, the members of the ship's crew, will be forced to live under the conditions of the close confines of the cabin of the craft with limited possibilities for motion and with monotonous circumstances of work. Therefore, it is especially important to plan ahead of time such types of organization of work and rest for the crew which would compensate for this deficiency.

In order to characterize the work activity of astronauts, it would be necessary to indicate also those junctures which are connected with some change in work motivation.

In the lives of people on Earth, some of the most important motivations to work activity are social stimuli and encouragements which in one form or another (payment, compliment, recognition of a job well done, its necessity, high quality) reward the work of a person. Astronauts who have completed flights on ships of the Vostok type accomplishing a special mandate of their native land are aware of their high mission, and the knowledge of their reward upon their return could be a powerful stimulus for work activity. How then is motivation provided for work on long flights lasting years when social recognition of this work would be delayed for a very long time?

The special necessity for development of recommendations for the rational organization of work and rest periods (in the broad sense of the word) for astronauts follows from very general observations on the conditions of astronauts' lives discussed above. This will facilitate successful work and life in the confined space of the space ship's cabin during flight. In order to develop such recommendations, one must bear in mind the need for a well-selected crew, the proper structuring of rest (reasonable recreation), a rational regimen of work (a normal load), etc. All these questions must occupy a central place in forthcoming investigations. It is now very important to define the end goal of this work and to evolve adequate methods for investigations.

THE PHYSIOLOGICAL BASIS OF HUMAN ADAPTATION TO SPECIFIC CONDITIONS OF ACTIVITY

S.A. Kosilov and B.A. Dushkov

ABSTRACT: The human organism generally functions on a precise schedule in accordance with the normal conditions of the daily dynamic stereotype. Hence, a person's capacity for work is established. Under the conditions of a space flight, the work and rest regimen must be grounded on this basis, taking into account the necessity of a gradual but significant restructuring of the astronaut's physiological functions. Specific conditions of the astronaut's activities must be determined in order to overcome the difficulties produced by the environment and to design a satisfactory program for work activity.

With the transition to the performance of work under the conditions of space flight, the human organism experiences a significant restructuring of functions*. The astronaut can tolerate the effects of such factors as velocity, vibration, weightlessness, etc., after the corresponding conditioning directed to the development of an physiological tolerance and endurance to all these unfavorable factors. But the organism of the astronaut also must be well adapted to a definite order of activities and to a sequence of work and rest periods. /14

A poorly grounded regimen of work and rest can elicit and hasten the development of fatigue which is a real threat to the health of the astronauts and lowers their capacity for work.

In the report of the astronauts A.G. Nikolayev and P.R. Popovich, it was noted that all aspects of the work during flight were fulfilled by them easily and their general conditions were outstanding. However, several physiological indices of life activity and of ability to perform work at the end of the flight bore witness to the presence of fatigue. Thus, six hours after landing hyperventilation was observed in the astronauts, with a rise of 24% in the oxygen demand and 30% in the elimination of carbon dioxide. Corresponding changes indicating development of fatigue in the astronauts was established also by a change in the neurodynamic character of responses on the part of the bioelectric activity of the cerebral cortex, which were manifested as a predominance of alpha-rhythms in the central occipital leads.

*Ed. note: physiological indices

Moreover, a slight reduction was observed in the quantity of erythrocytes in the peripheral blood, and there was an increase in the total protein and serum mucoids in the blood. Also noted was the significant content of the desoxycytidinoid fraction in the daily urine and an increase in the quantity of 17-21-hydroxy-20-ketocorticosteroids and creatine. Changes on the part of various functional systems (phase of heart cycle, external respiration and gas ex- /15 change, EEG, etc.), detected in the astronauts V.V. Tereshkova and V.F. Bykovskiy at the time of the second group of space flights during the 1-16 day period after the completion of the flight, corresponded over all to a profile of general fatigue. Both the degree of the appearance of separate symptoms of fatigue and the character of the physiological reactions appear to have markedly individual peculiarities (N. I. Sisakyan, 1964, 1965).

In generalizing results of the missions of the American astronauts and experiments on airplanes, in anechoic chambers and in observation of the special contingencies of people exposed to extended durations in a small room of authors (David 1961; Violette 1964, and others), considers that the adaptation of man to space or to conditions simulating a space flight proceeds according to definite laws. Human response to prolonged exposure to a complex of factors (weightlessness, G-loading, acceleration, isolation, etc.), appears to be unfavorable, although neither the flights accomplished up to the present time nor terrestrial experiments serve as a basis for any decisive conclusions. According to the opinion of these investigators, during the course of further flights of greater duration optimal conditions must be defined which can be created in the cabin of a ship for the support of the normal capacity for work and of the psychological status of the astronauts.

All these data attested to the fact of the development in the astronauts of definite fatigue, and thus the problems of scientifically based prophylaxis of this condition are of real essence. One of the effective means of this prophylaxis is a rational regimen of work and rest.

As an approach to the design of a regimen of work and rest for astronauts, the use of one of the well proven regimens worked out for terrestrial conditions might be proposed, for example, the regimen of workers at a control panel. Life and practice obviate such a practical approach to the solution of the problem. We will indicate the basic reasons for its untenability. First of all in the organization of work on Earth, we have great possi- /16 bilities for varying the work process conditions, adapting them to the peculiarities of human organisms. Thereby it is frequent that a regime close to the optimal is found through experience, i.e., by means of comparison of the variance presented by life itself and by industry. For example, it is possible to arbitrarily change the beginning and end of working shifts, the time of the lunch break and of additional regulated breaks, etc.

Under conditions of space flight, the sequence of work, of periods of sleep, and of types of rest is evidently subordinated to a significant degree to the idiosyncrasies of technical devices and to a special assigned task program (communication with Earth, with other astronauts, automatic and manual guidance, regulation of the conditions of the environment, etc.) which do not have a close analogy to terrestrial work activity. Moreover, astronauts are subjected around the clock to the effects of specific factors of the external environment in which weightlessness has a particular significance. One must also consider the extremely intense stress and responsibility involved in the work of astronauts.

Therefore, it is hardly possible to utilize any of the specific work-rest regimens developed under Earth conditions in their currently existing forms. It may be affirmed with all certainty, however, that the general physiological work adaptation laws lying at the basis of work capacity dynamics which dictate at which juncture work will be followed by fatigue are manifested uniquely in all forms of work activity, including that of the astronauts.

For the investigation of these problems, two directions can be used; the first-a step by step investigation of a series of experimental regimens with a thorough characterization of the productive efficiency of the test subjects in the study and of changes in their physiological processes, the other-investigation into the laws which define the optimal adaptation of a man to a specific job, the clarification of the dynamics of change in work capacity, the concrete physiological mechanism of productive practices, and the productive fatigue of astronauts. Investigations in the first direction can be carried out to define a regimen of work and rest more or less approximating the optimal only after /17 the testing of a great number of possible variants chosen at random without any physiologically-based system. Investigations in the second direction can be carried out in the most direct way for the designated goal of the structuring of an optimal regimen of work and rest, in which the succession of work and rest periods is based upon physiological laws. In the development of an optimal regimen of work for astronauts, it is necessary to use creatively all of the general laws of the dynamics of the capacity for work which are found in the physiology of labor in every experience of the physiologically-based structuring of a regimen of work and rest for workers on various specialities. Depending on technical conditions (involving the use of machine tools, control panel monitoring, assembly line duties), work physiologists today are availed the possibility of deriving--even on a practical basis--an optimal work-rest regimen for workers in various branches of industry and for those occupied with various types of work by the shortest method based on the characteristics of industrial processes and processes taking place within the worker at a physiological level (S.A.Kosilov, B.A. Dushkov, 1964). Experience in the development of physiologically-based optimal regimens of work and rest must be used, even for structuring of regimens of work on the part of astronauts, taking into account the technical conditions of the work and the physiological laws of the organism's adaptation to the specific work activity. The useful general laws which must necessarily be taken into account for the development of the regimen of work of astronauts are, first of all, the general laws of the dynamics of change in human work capacity. The correct regimen of work and rest is characterized by starting work promptly and by continued maintenance of a high and stable level of capacityto work or by moderate fatigue. In order to develop measures for prophylaxis of fatigue, it is necessary to pay attention not only to the last stage in the dynamics of the capacity for work, but also to all three periods. Therefore, one must keep in mind the general physiological laws of exercise and conditioning* which must be regarded in structuring a regimen of training and work for the astronauts.

For the physiological basis of an optimal regimen of work and rest for an astronaut, one must use quantitative data on the physiological mechanism of exercise, conditioning and fatigue. In this regard the principles of the concentration of muscular exertion and neurological processes and the formation of work dynamic stereotypes in the course of exercise have a definite meaning (S.A. Kosilov, 1938, 1941, 1954, 1955, 1963). /18

In the Fifties, work physiologists relying on physiological studies of the work dynamic stereotypes and of the change in the functional condition of the neurological system in the work process (concentration of muscular strength and neurological processes, accumulation of residual impressions produced by excitation), worked out a method for a physiological-based structuring of an optimal regimen of work activity. It was established by S. A. Kosilov that as a result of exercise, a diminution of the intervals of time required for the basic performance of separate motor acts (a development of speed and acceleration maximums); it has been shown that the formation of this type of work capacity is a function of the exercise performed in that during the initial stages of the movement, conditions are established which promote the most efficient execution of subsequent stages of the movement. This bears witness to the blending of movement into a complete motor act performed according to a set pattern. It is necessary to view this blending of formerly uncoordinated elements of movement on the physiological side as a unique manifestation of a systematicity of higher neurological activity conditioned by the specific work activity--this is the principle of dynamic stereotype. Insofar as this manifestation cannot fully be identified with the dynamic stereotype in animals or with the motor dynamic stereotype, in the treatise of A.N. Kresovnikov (1954) and of M. I. Vinogradov (1958) it was expediently termed the work dynamic stereotype.

* Ed.note: Literally, this signifies adaptation to physical stress through exercise conditioning.

A study of exercise with simple and complex movements and of work with variation in the duration of micropauses under conditions involving various activities shows that concentration of neural processes during exercise is connected not only with the effect of conditional support of the attainment shown by the result, but also with the change in the functional status of the nervous system as a consequence of the accumulation of residual impressions from excitation which remain after the end of each successive movement. The above-mentioned regular laws are true of activities demanding mainly a strain on the attention for solving mental problems as well as for physical labor. Thus a study of the residual impressions from excitation remaining after the completion of a simple visual motor response showed that they can be noted 8-10 seconds after the end of the motor response, that is, such an interval of time in the course of which a new work activity or movement may begin and develop (B. S. Volkov, S. A. Kosilov 1965). During fatigue from mental work, this time lapse increases while after rest it diminishes.

A uniqueness in disarray of the work dynamic stereotype is observed also in the sequence of preparation for flights and in people who find themselves for a long period of time under conditions approximating those of space flight. From the point of view of physiological studies on work dynamic stereotype, one of the characteristic specifics of astronaut work appears to be the limitation of stimuli signalling the results of activities and the limitation of the possibility to accumulate residual impressions from excitation. On the basis of these properties it is possible to assume that with astronaut fatigue, the status of the nervous system must change due to a lowering of concentration of neural processes in the dominant focus of excitation, which in turn can appear as the cause of a retardation of work function and the development of subjective feelings of difficulty in performing motor activities. On checking with the aid of the method worked out by us (B. A. Dushkov, 1965) on the basis of a study of work dynamic stereotypes and change in nervous system status, objective data characterizing the specifics of this fatigue were gathered; thus after two subjects, O. and C., stayed for five days under conditions simulating several aspects of space flight (posture, nutrition, regimen of life, etc.), the responses and stability of time-strength responses noticeably changed. In both subjects, a lowering of muscular endurance occured. With subject C., the ability to maintain half maximum strength for long periods diminished from 38 to 31 seconds; with subject O., this index decreased from 53 to 42 seconds. At the same time, there was almost no change in muscular strength. After the experiment the subjects made more mistakes in reproducing small and great physical [isometric] exertions. There were observed changes in the perception of fixed time intervals (see Table 1). As the data concerning the changes in response indices after the 5-day experiment in Table 1 show, the subjects experienced a decrease

TABLE 1. CHANGE OF TIME AND STRENGTH INDICES BEFORE AND AFTER THE 5-DAY EXPERIMENT.

No.	Index	Subject Ch				Subject O			
		Before Experiment	Difference	After Experiment	Difference	Before Experiment	Difference	After Experiment	Difference
1	Muscular strength (Kg)	48.15	-	45.15	-3	42.1	-	42.1	-0
2	Strength endurance (seconds)	38	-	31	-7	53	-	42	-11
3	Pause 10 seconds	8	-2	13	+3	9	-1	4.0	-6
4	Small force	15	-5	30	+10	25	+5	30	+10
5	Pause 10 seconds	8	-2	13	+3	9	-1	8.6	-1.4
6	Large force	95	+5	110	+20	100	+10	120	+30
7	Pause 10 seconds	10	0	12	+2	9	-1	6.0	-4
8	Small force 3 seconds........	$\frac{30}{2.5}$	$\frac{+10}{-0.5}$	$\frac{35}{2}$	$\frac{+15}{-1}$	$\frac{30}{2.7}$	$\frac{+10}{-0.3}$	$\frac{30}{4.4}$	$\frac{+30}{+1.4}$
9	Pause 10 seconds	12	+2	8	-2	9.5	-0.5	9	-1
10	Large force 3 seconds........	$\frac{80}{2.5}$	$\frac{-10}{-0.5}$	$\frac{110}{2}$	$\frac{+20}{-1}$	$\frac{95}{3}$	$\frac{+5}{0}$	$\frac{80}{3}$	$\frac{-10}{0}$
11	Pause 10 seconds	8	-2	8	-2	10	0	8	-2
12	Small force 10 seconds.......	$\frac{18}{9}$	$\frac{-2}{-1}$	$\frac{55}{8}$	$\frac{+35}{-2}$	$\frac{24}{9.5}$	$\frac{+4}{-0.5}$	$\frac{15}{10}$	$\frac{5}{0}$
13	Pause 10 seconds	10	0	7	-3	10	0	10	0
14	Large force 10 seconds.......	$\frac{80}{11}$	$\frac{-10}{+1}$	$\frac{110}{6}$	$\frac{+20}{-4}$	$\frac{100}{10}$	$\frac{+10}{0}$	$\frac{80}{10}$	$\frac{-10}{0}$

Notes. (1) Indices in No. 8, 10, 12, 14 are given as fractions: in the numerator--the applied force in arbitrary units; in the denominator-duration of time intervals.

(2) The subjects were directed to exert a small force--20 arbitrary units-and a large force--90 arbitrary units.

in ability to differentially evaluate time intervals and their own muscular exertion. This is decisive proof that a "deconcentration" of nervous processes occured.

For example, upon completion of the tests after the experiment, subject C. experienced a diminution in the accuracy of defining 10-second intervals of time by shortening them 30-40%. Moreover, the error in reproducing small exertions at 10-second intervals of time increased by 35 conditional* units. Having analyzed the difference in the results of tests carried out according to separate indices of the time-strength response before and after the experiment, it is possible to conclude that in a given case a great difference in coordination of movements, static endurance and judgement of intervals of time appears. The reliability of the neuromuscular apparatus diminished in the production of assigned physical work, and the functional possibilities for fulfilling an established amount of a programmed intellectual activity in the course of a given length of time also diminished.

A "deconcentration" of the nervous processes in connection with a 5-day stay in a chamber of small volume was demonstrated with the aid of a method for defining physical exertion and time by counting orally. In this method, the subjects were presented with the task of squeezing a dynamometer with maximum speed in sequence according to a given program, and to total mentally the amount of kg of effort applied. After exposure to the experimental conditions, there is an increase in the number of errors allowed in performing the exertions, and the quantity** of intervals between successive squeezes of the dynamometer grew. In various positions, these indices after the experiment changed nonuniformly. The greatest number of errors were noted when the subjects were in the standing position or lying on the stomach. Upon completion of the test (oral count) in several positions (sitting, lying on the back), the /22
time of the count was shortened, which evidently implies a certain facility through practice of the subjects in this activity.

By means of observation and interrogation, it appeared that the subjects first noted fatigue on the third day of their stay in the chamber. They experienced pain in the knee joints and a general worsening in their well-being (weakness).

After we have diagnosed the presence of special fatigue in the subjects and have elucidated its physiological mechanism, it becomes necessary to design a means of prophylaxis for fatigue by means of optimalization of the work regimen. In fact, on the basis of experimental data, several criteria for the definition of dynamic change in the subjects' nervous systems were derived, from which it is possible to define the early stages of impairment of the work dynamic stereotype. The ascertainment of the early stages of specific fatigue is a decisive condition for the successful prophylaxis and optimalization of the regimen of work and rest

*Ed.note: "Conditional" units are those devised for the specific experimentation.
**Ed.note: sic! It would seem that the original meant to state "magnitude", however.

in extreme circumstances.

A study of specific exercise processes in industrial innovators* (S. A. Kosilov, 1959) and in students (Z.N. Briks, S. A. Kosilov, 1963) led to the discovery of the great significance of planning a worker's activities for the mastering of complex labor operations and of constantly comparing work activities performed with concepts of correct manipulations. Simultaneously, with the latter, a refinement and specification of the integral model of work activities can take place because of the enrichment of motor experience.[1] The data available in the literature shows that for work connected with the operation of remote-control apparatus, there is a characteristic formation and reproduction of an "operative model" (D. A. Oshanin, 1966). Evidently, this factor has great significance in /23
the work and in the regimen of living activities of an astronaut. A physiological analysis of the integral model of work activities showed the most important conditions for its reliability. For the perfection and maintenance of an integral model of work activity, it is necessary to have an impression in the cortex of the cerebral hemispheres of residual impressions from excitation from correctly fulfilled, most effective variants of work operation. These impressions accumulating with repetition or upon starting work, reach such a level of intensity that they give rise to conscious ideas about the best variant for the performance of a given work activity. Some of the residual impressions from excitation may remain below the threshold of sensitivity and still influence the control of work motion. There is a unification into a single system of ideas of the correct method of performing work operations (received with instruction) and the unconscious residual impressions from excitation of the motor analysors which is a unique confluence in the work process and an interaction of the functions of the primary and secondary signal systems. A summation of what will take place in the work regimen evidently will depend upon the accuracy of the integral model of work activity.

For the successful mastery of skills and for rapidly acquiring skill through experience, it is important before starting the work to recite verbal instructions at the time of performance of the exercise. A person's formation of a clearly defined integral model

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[1]The idea of an integral model of work activities developed by S.A. Kosilov (1965) corresponds to the physiological mechanism of the collation of work activities taking place at a given moment, with those which were planned and printed in the prior experiment. It has been experimentally established that the net indicated correspondence is based on the accumulation of the vestiges of excitation of the stimuli coming from perceived instructions, and from direct action on the nerve endings of the analysors, including a number of the motor analysors.

*Ed. note: In the USSR, "Innovator" is a term often applied to laborers who exceed their quotas by wide margins.

of work activities is markedly facilitated by correct work conductor behavior, which can facilitate programming the behavior of a person under specific circumstances.

Under the influence of various factors acting upon the physiology of the astronauts, the integral model of work activity undergoes changes which are expressed by nonuniform weakening of its various components; in particular those connected with the excitatory residual impressions in the primary and secondary signal* systems. It is known that a subject in a pressure chamber under conditions of lowered pressure will write an account of his sense of well-being marked by sharp disturbances in the handwriting. A. V. Eremin, I. I. Kasyan, I. A. Kolosov, V. I. Kopayev, and V. I. Lebedev (1965) indicate that, according to their observations, as- /24 tronauts on long flights develop sensory and motor function disorders connected with a feeling of fatigue.

This leads to the conclusion that in the regimen of work of astronauts, it is necessary to bear in mind exercises directed towards the maintenance and strenthening of the integral model of work activity; in particular, exercises which include both motor activities which are internally consistent and the solving of mental problems: that is, the simultaneous fulfillment of responses to a complex of stimuli, including direct stimuli and stimuli addressed primarily to the secondary signal system. As far as experiments with students are concerned, there appeared to be a positive influence of the simultaneous repetition of verbal instructions with a corresponding work movement. Analagous to this in our experiments (B. A. Dushkov, F. P. Kosmolinskiy, 1966), the favorable action of special exercise on the work capacity of subjects was established, bearing in mind the activity of the primary and secondary signal systems and the simultaneous performance of motor actions and oral counting.

The final period of dynamic work capacity is characterized by the development of fatigue. The study and development of fatigue permits one to draw the conclusion that fatigue under specific work conditions is closely connected with a regular change in the functional structure of the nervous system, as a consequence of prolonged accumulation of the excitatory residual impressions.

Moreover, upon attainment of a high level of capacity for work, any further continuation of work and addition of residual impressions does not lead to a heightening of awareness and functional mobility of the systems of the work dynamic stereotype, but rather to their lowering, according to the law of parabiosis of Vvedenskiy. Concrete manifestations of this regularity of work processes under terrestrial conditions was observed in the study of the dynamics of the work capacity of laborers at the time of shift changes. Thus, for example, in switchboard operators there was observed a heighten-

*Ed.note: Throughout this discussion, "signal" is meant to convey "arouse" or "arousal" in a psychological sense.

ing of the functional mobility of the visual analysors (established by determining critical frequency of phosphene) and of awareness, (defined by the magnitude of the threshold of the electrical excitation of the optic nerve), in the course of the first two hours of work, and a reverse change in these indices at the end of the working day (A. I. Kikolov, 1955). In the given example a change was observed in functional mobility and the visual analysor; in other such works, analogous dynamics were established in the status of the motor analysors (T. N. Pavlova, 1954. /25

A lowering of excitability and of functional mobility (lability) elicits disorders in the concentration of neural processes as a consequence of an impairment of the work dynamic stereotype. Thus on the basis of the data received in the study of the physiological processes examined above among workers under various conditions, the possibility is presented of discovering the physiological essence of fatigue as an impairment of the work dynamics stereotype as a consequence of the change of the functional condition of the nervous system (lowering of excitability and of functional mobility of the nervous system in the development of parabiotic inhibition). Besides this, it must be considered that the basic process comprising the essence of fatigue appears differently, depending upon the peculiarities of the specific type of work. In this regard, it is especially important to consider two circumstances. In the first place a disorder in concentration of the neural processes and impairment of the work dynamic stereotype does not equally influence the functions of the various analysors of the system components. Usually there are observed changes primarily in those functions which participate above all in the work process. Thus, for example during heavy physical labor, changes in physiological functions will be different from data obtained by studying fatigue in stereoscope operators. In the first instance, changes will be observed in the functions of the muscular system, and in the second case, in vision. In the second place, neurodynamic disorders connected with industrial fatigue do not immediately lead to an impediment or to a curtailment of actual work. For the most part, a person in a fatigued condition will continue work for a certain length of time, seeking various means of adaptation to the altered status of work capacity.

We will treat certain laws of physiological processes characteristic for those engaged in intellectual work. During intense intellectual exercise demanding special concentration and attention /26 and the swift performance of a great number of intellectual operations, the capacity drops comparatively quickly, which is demonstrated by the diminution in hourly productivity beginning with the 4-5th hour of work (T. N. Pavlova, 1957; V. P. Solovÿeva, 1957). Upon the completion of such work, the accumulation of excitatory residual impressions continues noticeably longer, which leads to the development of deeper stages of the parabiotic process in the cortical regions of the motor analysors, and to the rise of radical counter-measures to fatigue, such as preservational inhibition, which protect the nerve cells from excessive exhaustion.

The period of productive work activity comprises a comparatively short length of time in the daily period of a person's life. In the development of a daily regimen of work and rest, one must consider that after the completion of productive work, a person switches to other activity; separate and with a dominant type of behavior different from that of productive labors.

In the construction of a daily regimen for work and rest, diurnal changes in physiological functions must be considered. More over, it is necessary to consider that the diurnal rhythm of physiological functions is genetically fixed and by the personal experience of each person in regard to a complex system of conditioned reflexes (eating, resting, sleeping, etc.). This series of activities forms the so-called diurnal dynamic stereotype which is characterized by a rise in the excitability of the sympathetic nervous system and of the motor apparatus in the daytime hours, and by a lowering thereof at night.

In a different regimen of work and rest, depending on the peculiarities of the specific type of work and also on various, sometimes permanent disruptions of the usual tempo and rhythm of work, various deviations from the typical daily periodicity can occur.

The question as to the adaptation to a new regimen of work and rest and to changed diurnal physiological function dynamics was the object of investigation by a number of authors.

Thus, for example, in the work of Raboutet et al. (1960) it was noted that adaptation to a new regimen or work and rest among pilots flying great distances was very difficult. Lewis and Lobban (1954) observed the physiological condition of 8 subjects living a 22-hour day (at Spitsburgen). One of them experienced a restructuring of rhythm; the other 7 consistently followed a 24-hour daily rhythm. /27

Haute (1960) carried out an interesting experiment in the changes in work capacity on subjects placed in a special room. The subjects were exposed to the following regimen: 4 hours of work, 4 hours of rest, and again 4 hours of work, etc. The work consisted of activities with complex systems of control. The mean value of productivity was considered, which for each operator was evaluated at 8-hour intervals. The author notes that adaptation differed with different individuals. For several functions of the operator (for example, the recording of instrument readings) the diurnal rhythm is shown to be much weaker for the same functions with several other operators. The degree of adaptation of an individual operator differs with the various aspects of activity; for example, with the recording of data recognition work at a radar screen. For one of the operators, whose diurnal component was expressed expecially distinctly, adaptation to an 8-hour day appeared to be extremely difficult. Evidently the degree of adaptation to an artificial external regimen depends on the restructuring of rhythm in relationship to various changes in the conditions of life activity.

In studying the daily rhythm of autonomic functions during space flight (G. V. Altukhov, P. V. Vasil'yev, 1965, et al.) it was noted that during an extended period, a man exposed to weightlessness undergoes a number of changes in autonomic function--pulse rate, breathing, body temperature, and diurnal rhythm--the mechanism of which, in the opinion of the authors, probably is connected with the specific effect of weightlessness as well as with emotional strain.

For the organization of a daily regimen of work and rest of an astronaut, the important conclusion of a number of works dedicated to the study of daily periods of physiological functions (S. O. Ruttenburg, 1963; G. M. Gambashidze, N. I. Naslodova, 1965, et al.), concerned the possibility of an organism's adaptation to a changed daily regimen. As an index of such an adaptation, the amplitude of diurnal fluctuations of several physiological functions (body tem- /28
perature, pulse rate, work capacity, etc.) may be used. There appears to be more lee-way in relationship to the daily regimen in the function of the musculature and nervous system than in the inert processes of temperature compensation and blood circulation. Changing the daily regimen under the control of this index, one can purposefully change the diurnal dynamics of physiological functions. Under certain circumstances, the work can effect a shift in diurnal rhythm. Thus in the investigations of V. P. Solov'yeva and G. M. Gambashidze (1960), it was noted that diurnal rhythm of physiological functions of a person working during the night was preserved without changes; but also M. A. Gritsevskiy and Ye. A. Fat'yanova (1964) note that the internal rhythm of physiological functions showed changes in comparison with the usual daily period among operators in the chemical industry working the night shift.

Experiments on animals were carried out establishing the possibility of the change in daily periods of life functions. According to the data of G. I. Shirkova (1949), in monkeys (*Macaca lapunderi*) a distinct daily rhythm of conditioned reflex activity is observed, which is expressed by the fact that the monkey completely refused to respond to complex condition signals at night. However, simpler well established stimuli could induce complete responses (E. M. Cherkovich, 1961). As the investigation of Den Su I and K. P. Ivanov (1961) shows, a change (inversion) in the light regimen with illumination at night and darkness during the day by the fourth daily period brings a corresponding restructuring of the rhythm of motor activities in animals (fat loris*). Corresponding changes in gas exchange, respiration rate and body temperature reach their full expression noticeably later, on the 11-12th day.

In the experiments of O. P. Shcherbakova (1938,1959) on monkeys, it was established that with the creation of a rhythm of life under which animals found themselves under artificial illumination and received food at night, and in the day found themselves in

*Ed.note: Reference here is to *Loris tardigradus*, the "slow loris".

darkness and did not receive food, they underwent a full restructuring of the usual dynamics of life functions. Under the influence of such conditions, a change in the diurnal rhythm is noted whereby intensification of life functions in the animal took place during night hours, and a lowering during daylight hours. /29

Applicable to the solution of the problem of the physiological basis of the diurnal regimen of life activities in an astronaut, a decisive significance is acquired by the clarification of the principle possibility of the restructuring of daily periodicities, in the sense that an increase in excitability of the autonomic functions and motor apparatus would have developed in his waking hours during work at nighttime. If one agrees with the opinion of O. I. Margolina (1954) as to impossibility of such restructuring, the reordering of work is impossible and the life of an astronaut must be structured strictly in keeping with terrestrial rhythm. The authors maintain that to distort the human diurnal rhythm experimentally almost cannot be done successfully.

Interesting observations were made by I. C. Kandror (1954). He showed that under specific conditions as, for example, traveling by train from Moscow to Vladivostok, after 8 days of travel the diurnal rhythm is restructured. Among the passengers on the train, after 3 days a restructuring of the diurnal stereotype already had taken place. As is well known, between Moscow and Vladivostok there is a time zone difference of 7 hours. For each day of travel, the whole system of life for the passengers shifts one hour. Correspondingly, their behavior changed. Passengers began to get up, to go to sleep, to eat, to go out into the stations not according to Moscow time but according to local time. Coincidentally, changes occurred in the times when the index of physiological functions (body temperature) reached its highest and the lowest values.

Another investigation by the same author noted that among people in the far north during the polar day and night, various disturbances of a compensatory nature and in the amplitude of the daily body temperature curve are observed. During the polar day, most often a prolongation of the day phase is noted; in the period of polar night, there is a prolongation of night phase. The author is inclined to view these data as an indication of a change /30
in the balance of the excitatory and inhibitory processes in the cortex of the cerebral hemispheres, depending on the intensity of natural illumination.

A comparison of the data presented above indicates that shifts in diurnal stereotype functions in a person take place easily if the entire way of life changes at the same time.

Investigations in chambers showed that adaptations of subjects to the usual 24-hour cycle (with sleep other than at night) took place more quickly (by the 8th day) than to an 18-hour cycle. Evidently the restructuring of the periodicity of sleep and wakefulness have great significance here, and did not correspond to external rhythms. Evidently adaptations to new diurnal rhythms are formed, gradually overcoming former temporal relations among periods of sleep, work and rest.

In connection with the materials examined, the question concerning specific measures facilitating adaptation to diurnal rhythms acquires great significance. As far as astronauts and subjects in small chambers are concerned, it would be interesting, along with the physiologically based motor regimen, to test the action of hypnotism (for example, by means of flashing lights and of electronarcosis) and also, for example, of other means of regulation of the inhibition and excitation processes, including several pharmacological ones.

With the design of a regimen of work and training of an astronaut in preparation for long flights, it is necessary to consider that the circumstances in which there are regular transitions of the various states of work capacity, the beneficial influence of rest, and the resumption of work at former intensity are associated with a stable, reliable system of reflexes--the work dynamic stereotype and its most important component--the integral model for work activity.

The multifaceted activity of a man in society is the source of necessary stimuli for the formation and support of an integral model of work activity--a concept concerning the goal of work "which as a law defines the mode and character of his activity to which he must subordinate his will"[2]. Based upon these considerations, it /31
is necessary in the process of preparation for the specific conditions of astronaut activity, not only to establish conditioning in order to surmount difficulties of an exogenous character in order to be able to withstand the severe effects of external factors, but also to evolve an adequate program of work conduct, insuring high levels of goal-oriented intellectual and physical activity.

[2] Karl Marx, *Capital*, Vol. 1, Moscow, 1949, p. 185.

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THE RATIONAL DESIGN OF A REGIMEN OF WORK FOR ASTRONAUTS.

F.P. Kosmolinskiy and B.A. Dushkov

ABSTRACT: Experiments have evidenced the changes in bodily and mental functions which result from the unique environment peculiar to space flights. The author discusses these and proposes methods of organizing the astronaut's work and rest regimen to compensate for and/or avoid these changes.

At the present time it is still not possible to compose a professiogram of the work of an astronaut. In literature there is almost no information on this problem. In the published works it is basically the capacity for work of subjects under terrestrial laboratory conditions simulating several factors of space flight that is observed. (F. D. Garbor, et al., 1963; N. N. Gurorskiy, et al., 1966).

A correct regimen of work and rest promotes a high level of /33
human work capacity for extended periods, thus preventing fatigue and overtaxation. Elevation of pulse rate, arterial pressure, frequency of respiratory movements and lung ventilation, and an increase (or a decrease) in emotional excitability etc. during work performance must be viewed as an indication of excessive strain on the astronaut and of the difficulty and tedious nature of the work. A deeper degree of fatigue appears in the form of a prolonged worsening of physiological indices and with sharp fluctuations in the duration of work periods.

It must be noted that there is no strict proportionality between the magnitude of these functional changes and the degree of difficulty of the work. The level at which a given function is established in the course of an extended length of time can be a consequence of physiological adaptability rather than a sign of fatigue.

A rational regimen of work and rest for astronauts must be constructed on the basis of these functional indices. Also specifications of the work and of factors influencing the condition of the astronaut's physiology must be considered (emotional strain, isolation from the external world, heightening of sensory feelings or of insufficiency, small amount of motor activity, elevated concentration of attention, the unusual circumstances of weightlessness, etc.).

I.M. Sechenov emphasized that in order to work without tiring, it is necessary to have a definite relationship between the factors of work (frequency and strength of movements and also the size of the obstacles to be surmounted) and the length of the rest periods.

It is well known that the human work capacity changes regularly or in a regular manner during the course of the working day.

At the beginning of the working day, the "working-in" phase lasts for 1-2 hours. It is characterized by the gradual elevation of the work capacity and of the amount of productivity of labor at the end of work. Such productivity is indicated by the rise in hourly output, which is a function of the speed of thought processes and of the work movements, the development of motor con- reflexes, functional mobility, concentration of neurologi- /34 cal processes, etc. After that begins a period of work capacity characterized by a sufficiently extensive stability in the work capacity level. In the third period a lowering of the indicated capacity for work and of productive work is observed, evidencing the onset of fatigue. Before the end of the working day, it is often possible to define one more period: the final rush in which work capacity is improved for a short time.

Measures taken for hygienic work must facilitate the maintenance of a high capacity for work and the avoidance of fatigue. With the appearance of the first signs of fatigue, small recesses are recommended, which may be either passive or active (fulfilled by means of specially selected physical exercises). The question of the extent of each break is decided according to the level of strain and the nature of the work.

With physical work, this break is established by the time necessary for the restoration of the rate of cardiac contractions, lung ventilation, oxygen demand, etc., which in a majority of cases averages out to 5-10 minutes.

The first 3-5 minutes of this have a greater significance in the restoration of the physiological work capacity. Therefore, for organization of the regimen of work and rest of an astronaut, it is necessary to exchange extended breaks with more frequent short breaks. Another advantage of short breaks appears to be that during a non-extensive pause, the work setting is preserved.

During short breaks, the astronaut's rest may be either passive or active. Most effective is an active recess with physical exercises. Programs of physical exercises must be chosen, keeping in mind that unique factors of the external environment are acting on the astronauts: for example, weightlessness and the characteristics of his work. Experimental investigations show that for people occupied with intellectual labors, short breaks must be taken during each hour of work. Thus, in studying the regimen of work and rest of control panel operators in a television studio, it was established by A. I. Kikolov that the indices of /35 physiological function express positive adaptation to the work during the course of the first 3-4 hours, after which they indicate progressive lowering of the work capacity. Therefore, the duration of work at control panels was limited to 4 hours, 30 minutes per working day. During the remaining time (2-1/2 hours), the control panel workers were used for various other jobs. It was also recommended that work at the control panel be alternated with other processes. In the course of 4 hours and 30 minutes of work at the control panel, during each hour an active break of 10 minutes was established (three breaks during the working time). This regimen markedly improved the work capacity of the operators. In particular, pulse and arterial pressure stabilize, and during the time of program broadcasts, they rose insignificantly (maximal arterial pressure increased by 12 mm Hg without any change in the minimum).

The stereotyped alternation of work and rest is justifiably called by A. D. Slonim (1962) the life stereotype, including in this concept not only the appearance of muscular activity, but also rest periods for eating, sleep, etc. E. I. Brandt and O. I. Margolina (1954) show that disturbances of a given stereotype bring about a lower amount of work performed and a lowering of muscular activity. The cited authors established that a regimen of sleep and wakefulness, deprived of the rhythmic occurence of work and rest periods but preserving normal relationships of work and rest time, does not cause too great a disturbance in the normal diurnal rhythm or changes in body temperature connected with the appearance of a new response to the circumstances namely, the ability to sleep at any time of the day independent of a preceding period of sleep or wakefulness. Actograms* recorded during the time of sleep show the uniformity of its depth in the day and night hours. With a full disturbance of the rhythm of work and rest (with a falling out of rest in domestic circumstances) a disturbance in the daily curve was observed among the subjects; there was a rise of body temperature, pulse rate and arterial pressure during sleep time, especially during the night hours, which indicated a serious disturbance in the relationship of cortical and subcortical compensation. The daily stereotype basically reflecting the dynamics of /36 the distribution of the excitory and inhibitory processes may be changed with the disturbance of the conditions of rest promoting fatigue. With severe exhaustion, the dynamics of night sleep deviate from the norm; the actogram indicates restless sleep, and a rise in body temperature indicates functional disturbances in the diencephalic regions and particularly in the reticular formation.

In the structuring of daily regimen of work and rest the

*Ed. note: Also spelled aktogram--a record of bodily movements.

given baseline conditions must be kept in mind: (a) beginning and end of the work period; (b) the duration of sleep during the day; (c) the arrangement of meals; (d) change in the level of the organism's capacity for work during the hours of the day, bearing in mind that the astronauts will be on their own during the course of the day. The starting point for the projection of the regimen of work and rest for astronauts is the characteristics of the active cycles of life activity (work, sleep, active rest).

Chronometric data in the changes in duration of work operations have great significance. By means of curves of the durations of work operations and of microintervals between successive work operations, it is possible to come to a preliminary opinion on the ordering of a work and rest regimen. Rest periods must be taken at times which are most suitable for the work, including therein the processes of fulfilling personal relief.

Moreover it is necessary to consider the changes in a number of physiological indices according to the time of day, changes in the body temperature, in the sugar content of the blood, in hormones eliminated in the urine, in ascorbic acid, etc.

In the regularization of nonworking times it is necessary to keep in mind the individual interests of each participant so that he might spend the time fulfilling his favorite occupations.

Switching to a new activity in free or work time may be viewed as a different aspect of rest. It should not be continuation of the work which has been done during the course of the day.

For the distribution of work loads during the course of the day, it is necessary to consider the changes in the functional mobility of neurological processes toward the end of the working day.

According to the data of the Institute of Labor Hygiene and /37
Occupational Illness ANSSSR (S. A. Kosilov, 1957), upon the completion of uniform monotonous work, the functional mobility at the end of the working day diminishes in proportion to the monotony of the completed work, which appears as an increase in the duration of work operation. This shows that a change in the functional mobility takes place chiefly in that analysor which assumes a basic part of the work. For example, in assembly line work, changes in functional mobility are observed in the motor analysor; changes are observed in the visual analysor in proofreading work.

In the experimental work of V. B. Liberman and T. A. Trubitsyna (1954), it was established that the difficulty of work for a person is dictated by the combination of signals, verbal stimuli included, from the internal and external milieu associated with the amount of the work performed. Moreover, the formation of the work stereotype does not simultaneously embrace all physiological functions.

In the construction of a regimen of work and rest, attention must be paid to the problem of compensating for sensory deprivation during extended space flights and the organization of psychic stimuli (interest in the work). It is necessary to vary the work of certain work operations by avoiding automation as far as possible.

The activation of intellectual processes appears to be effective compensation for sensory deprivation, that is, the ability of astronauts to organize their thoughts and ideas. Moreover, it is impossible to forget the opinion of Ewrard (1959) who, in the work "Conditions of a Person's Stay in an Interplanetary Ship", emphasized that usually a person's mechanisms of adaptation to conditions of isolation and sojourn in a confined space are viewed from a purely psychological point of view. In actuality, however, they are more complicated, and hinge on a neurological and endocrine substratum. Extended or repeated stress can lead to the depletion of the adaptive possibilities of several physiological systems.

Henry (1958) indicates the importance of motivation and of moral qualities as factors providing the best indices of activity. The personality of an astronaut influences motivation, individual /38 response, and his relationship with other members of the crew. Jmus (1961) also noted the importance of motivation and achievement orientedness.

Experiments on isolation have shown that the visual apparatus must be engaged in constant activity (changes of illumination and chromatic scale), otherwise it looses the ability to perceive a stable image. Attention is also turned toward insuring a sufficient level of attention (vigilance) under conditions of isolation. In working with apparatus, especially with an oscillograph instrument, visual fatigue occurs after a short time (30 minutes). The administration of pharmacological substances (benzedrine) is proposed for the prophylaxis of fatigue and the elevation of vigilance.

Edward and Eddowes (1961) came to the conclusion that the construction of the space cabin in accord with the physiological demands of a man reduces the influence of isolation. Gerathewohl (1959) considers that an extended stay in an isolated cabin leads to disorders in the physiological functions of the organism, bringing on a sharp lowering of appetite, insomnia, abundant perspiration, irritability and loss of weight. The reproducibility of intellectual work (the addition and subtraction of single digit numbers) worsens, although not quantitatively but qualitatively.

The monotony of work and surroundings which characterizes the conditions of occupation of a space ship during an extended flight brings on diffuse inhibitions in the cerebral cortex as a result of monotonous, weak stimuli.

It was common for foreign authors, until recently, not to consider the question of a possible compensation for insufficient exteroceptive stimuli by proprioceptive ones; in particular, physical exercises with the aim of maintaining the tonus of the cerebral cortex at a proper level.[1] Nevertheless, the necessity of the inclusion of a strict motor regimen in the order of the astronaut's day was repeatedly emphasized by the native Russian investigators A. V. Korobkov (1962), T. T. Dzhamgarov (1960), et al.

This question has a definite significance in the plan of the theory of the inter-relationship analysors, worked out by Soviet scientists A. V. Lebedinskiy (1963), Yu. G. Grigor'yev, M. D. Yemel'yanov (1962), et al., on the make-up of the crew, on the tasks assigned to each member of the crew and on the nature and length of the space flight. /39

[1]Only on the Gemini XI flight were physical exercises included in the order of life for the astronauts, three times a day for 10 minutes.

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SENSORY DEPRIVATION IN SPACE FLIGHT

F.P. Kosmolinskiy and Z.D. Shchcirbina

ABSTRACT: The consequences of a lack of external stimuli and motor activity during prolonged space flights are discussed. Experiments show that isolation and sensory deprivation create complex physiological and psychological reactions in the human organism. Measures must be developed to prevent these disorders, which can involve several of the astronaut's physiological systems and lead to a decrease in his capacity for work and other psychological manifestations.

Extended space flights have brought to light several new /39
biomedical problems connected with the activities of astronauts under new and unusual conditions of existence. One of these problems is the study of the capacity for work in a confined space. /40

As a result of a lack of contact with the external world (closed space) and of little motor activity (space limited in volume), the sensory surroundings in space flight become a series of simple, monotonous and constantly repetitious stimuli.

A significant quantity of investigations have been dedicated to the study of the consequences of the influence of sensory limitations. Especially important are investigations dedicated to the study of the influence of the limitations of external sensory information on an organism under the conditions of isolation.

The influence of isolation has been studied from very divergent points of view: in a social and demographic level (prison isolation and life of hermits); in its psychological aspects in the formation of small collectives of residents and workers in autonomous colonies (in prolonged trips on small vessels and on submarines in polar expeditions). Casuistic instances of isolation have also been studied (shipwreck victims and speleologists in mining disasters); investigations for clinical purposes (study of the conduct of the psychologically ill); and finally on the experimental level, with the clarification of several theoretical questions of physiology and psychology, for example, the clarification of the mechanism of analysor inter-relationships, etc.

It is necessary to note that the question of sensory deprivation was already established in our country in the Twenties. The first person to pose the problem of the study of the influence of sensory starvation on the organism was I. P. Pavlov. In 1923, he published an analysis of the condition of a patient with diseased visual and auditory analysors, from which the conclusion was drawn that a definite flow of stimuli was necessary for the normal activity of the cerebral cortex. The weakening or the elimination of afferent impulses leads to the appearance of deep, so-called passive inhibitions. These fundamental conclusions lay the basis of the work of V. S. Galkin (1932), who showed experimental deprivation of vision, hearing and smell in a dog lead to the appearance and propagation of diffuse somniferous inhibition (passive sleep). /41

The systematic study of the influence of sensory insufficiency by special physiologists began abroad during the Fifties. In experiments, various conditions of isolation and sensory limitations were created by the most severe means (plaster casts, exclusion of analysors, etc.), or by relatively simple ones (staying in an anechoic chamber). Abroad, crueler forms of isolation were imposed as distinguished from those used by Soviet investigators, who were trying to simulate the circumstances of isolation conforming to the space flight practice. The concept formulated by Miller (1958) can be considered as a methodological precondition of work connected with the problem of sensory insufficiency; he concludes that in the lives of living creatures, specific informational processes must be differentiated, in contrast to the processes and phenomena having a thermodynamic nature. At the basis of this concept lies the initial standpoint of viewing the variety of processes and phenomena in organic life as information, the character of which is defined by the level of complexity of the organisms or living systems. Miller (1953-1958) attempted to unite the theory of information with the theory of G. Sel'e on the adaptation syndrome (stress) and the theory of "nervism". According to Miller, there is a definite connection between an organism and the environment through stimuli eliciting definite responses, which he defines as the concept of stress. Information enters an organism, and the organism responds to it in the form of outgoing information (responses).

In the opinion of Flaherty (1961), in space flight it is difficult to separate a particular stress on the changes brought about by it in the organism, and therefore a fully valid definition of the stresses and changes in the activity of an organism is possible through the unified efforts of various specialists. Werdwer (1961), however, did not attribute any great significance to stress under the work conditions of an astronaut, since he supposes that an astronaut by force of will can suppress a situation of physiological tension. Werdwer modified the concept of stress and defined it as a condition arising in the human organism engaged in the completion of tasks which hinder him in coping with his work.

The term sensory deprivation (further, we will signify this term by the abbreviation SD) will be taken to signify sensory understressing or sensory subprovision. /42

Isolation and Sensory Deprivation

A pioneer of experimental investigations in areas of the study of isolation and SD abroad was the great Canadian doctor, physiologist and psychologist, Hebb. In 1934, he had already carried out the first experiments placing subjects in SD boxes or soundproof chambers. Multitudinous experiments on animals, rats, rabbits and monkeys with the goal of studying the influence of SD on behavior and higher nervous activity were carried out by Lilly (1956), Bexton, Heron and Scott (1954), Heron (1957), Miller (1958) and others. These investigations showed that with SD, a condition of apathy, of motor activity inibition and of a general lowering of the tonus of cortical functions developed.

Analogous data were noted in observations by others. Thus a study of the psychological status of healthy persons exposed to SD were carried out by Petric, Collins and Soleman (1958), Petric and Ormasten (1958), Ruff, Levy and Thaler (1959), and others. Having noted a general lowering of psychological activity, the capacity for work and a lowering of emotional stability, they observed the appearance of a nervous condition, sometimes a feeling of hostility toward the experimenter and finally the disorganization of thought and of internal speech.

At the same time, experiments to study the influence of SD on the condition of people suffering from psychological and nervous ailments were carried out by Lilly (1956, 1960), Cameron (1963), Svab and Gross (1965), and others. Thus, if patients (schizophrenia, strong and severe psychosis) are placed in a dark room, even with incomplete sound isolation many of them will experience hallucinations, as well as excitement and other symptons of their basic illness, according to Cameron (1963). Hence the conclusion is drawn that reducing the flow of external afference, particularly by depriving a person of visual perceptions, among people with a weak nervous system, appears to be a unique model for the study of the influence of SD and the function of the central nervous system.

From the mid-Fifties, SD experiments attracted increasingly greater attention in scientific investigation centers of the Army, Air Force and Navy of the United States and Canada. Situations into which individual persons and groups of people might fall in times of war and peace by their own action on the nervous system are very similar to the action of SD (submarine travel, persons spending the winters in polar regions, temporary stays in uninhabited desert locations). /43

The results of these investigations were made public at symposiums in Boston, 1958, and at Harvard Medical School, 1959.

General Characteristics of Experiments

A great deal of experimental research carried out with the aim of studying the physiological influence of SD may be classified according to the degree of isolation and sensory information using the following methods:

(a) relative and more strict isolation (for the swift receipt of effect);
(b) limited communication with the external world in a room and in a small cabin (limited space);
(c) individual and group isolation, also having the potential for individual isolation within the group;
(d) relative restriction of movement (limitation in the size of the chamber) and strict restriction of movement (fixation with straps, casts, etc.).

Under the conditions of actual space flights, evidently a combination of the various types of isolation and limitation of sensory extra- and interoceptive stimuli will take place. Moreover, keeping in mind the small load on the motor analysor under conditions of weightlessness, it is possible to suppose that during a long period a cabin of a spaceship all the phenomena of sensory insufficiency will receive an even more pronounced expression.

Jaxon and Helly (1962), having analyzed several experimental works in this study of the influence of SD on the organism, assume that it is necessary to consider the following properties of given experiments: the nature and strength of stimuli, the value of the stimulus for the subject; the degree of the limitations of movement and the characteristics of social isolation.

Numerous methodological procedures have been used by various investigators for the diminution of the flow of afferent impulses, so it is possible to note the following:

(a) absolute diminution of sensory stimuli (Lilly, 1956; Heron, /44 1957; Henry, 1958, 1961; Edwin et al., 1959; Ruff, 1959; Ewrard, 1958; Ruff et al., 1961; Jonekcheere et al., 1959 and others);
(b) diminution of informational stimuli (Miller, 1953);
(c) increase in the monotony of sensory surroundings without removal of stimuli (laboratory psychological investigations at Harvard Medical School, 1959; Burns, 1963).

The experimental conditions were extremely varied. Diverse methods were used for volume limitation of the chambers and for the creation of the isolation conditions (dark room with anechoic walls; a soundproof room; a room with partial sound insulation or with normal sound properties; an SD box covered with plastic foam; etc.), and various means of sensory information limitations (special glasses taped over the eyes, earphones creating "white noise"; cardboard handcuffs; special gloves reducing tactile sensations in the hands and feet; water baths heated to body temperature; etc.).

Experiments varied in length and in strength (severity) of conditions. In all circumstances a homogeneous contingent of subjects was chosen for the investigations; it was separated into an experimental and a control group.

Results of the experiments were judged on the basis of analysis of the objective physiological indices, journal notations during and after the experiments, conversations with a psychologist and a psychiatrist (in particular, attention was given to the presence of visual and auditory hallucinations) and qualitative performance of various psychological tests. The general condition and conduct of the subjects were also noted.

The Influence of SD on the Human Organism

In analyzing the results of experimental material, it is possible to segregate all the changes which take place in the human organism under the influence of sensory information limitation into three basic groups:

(a) change in the function of the cerebral cortex;
(b) change in the emotional sphere; and
(c) autonomic changes.

According to the opinion of Heron, Bexton and Hebb (1956), the maintenance of normal mentally controlled activity demands a constant input of sensory information. /45 Extended isolation leads to serious changes in the psychic sphere of a person, manifested as an impairmant of his intellectual capacity for work. As a result of extended strict isolation, Ewrard (1959), Johekcheere, Henrotte et al. (1959), Denenberg, Morton (1962), and others noted among subjects the development of pessimism, of an anxious condition and of melancholy, of a lowering in the emotional tonus and intellectual capabilities. Graybiel and Clark (1961) also noted the same phenomena in their experimental investigations studying the conditions of aircraft piloting, and they observed that approximately 36% of the pilots on high-altitude flights in single-seat airplanes experienced a feeling of alienation from the Earth.

On high-altitude flights in balloons, as described by Simons (1958, 1959, 1962), a feeling of alienation from Earth was experienced and manifested as auditory and visual hallucinations.

According to the data of Henry (1961), Lilly (1963), and others, at the time of SD experiments inadequate behavior and psychic disorders were noted among subjects; various hallucinations were reported, either of a fantastic nature or corresponding to some real image. He concluded that there was the possibility of the appearance of psychopathological symptoms in healthy people under the conditions of space flights.

The experiments of Heron and Bexton (1956) carried out on students isolated in special boxes may be used as a characteristic example in the study of the physiological influence of SD. The subjects were located on comfortable couches in a reclining position. The possibility of visual, auditory and tactile perception was excluded artificially: glasses with light-absorbing filters were placed over the eyes, audiophones on the ears, and special cardboard cases on the arms. The taking of food and physiological functions were accomplished upon demand.

The response of such subjects was characterized by the appearance of a feeling of hunger for external impressions, which led to motor unrest (several of them, for example, beat their arms on the walls of the box). The subjects were bothered by lack of a distinct idea whether they should sleep or remain awake. The majority of them refused to continue the experiment after 24-72 hours. Visual /46
hallucinations appeared in those subjects who remained in the box for more than 2 days.

Hallucinations appeared in situations of especially severe limitation of sensory information. Ruff (1961), Henry (1958, 1961) and others noted this phenomena.

Chunningham (1960) indicates that at first a person responds critically to hallucinations under conditions of isolation; afterwards the critical relationship disappears, and they prevail. According to the opinion of Ruff (1961), hallucinations elicited by severe conditions of isolation may lead to a complete personality breakdown.

An important test for the selection of astronauts is experimental work done in a soundproof chamber. With many subjects, extended isolation elicits the appearance of hallucinations.

The more realistic the hallucinations are in content, the more danger they present for the piloting of a spaceship (Bohem, 1962).

In subjects placed in a soundproof chamber, Heron (1957) describes the presence of confusion of thoughts, false sensations and even hallucinations, as well as physical and psychological fatigue and boredom leading to a lowering of motivation.

Sanford, Silverman, Schmavonian (1962) and Van Wulften-Palthe (1961) have referred to similar instances of a lowering of the general physiological and psychological tonus and a lowering of motivation.

A number of investigators speak of the condition of tension arising under conditions of isolation, which some of them considered to be characteristic for the entire exposure to these conditions. Several researchers (Hanna 1962, Heron 1957, Sanford et al.1962;F.D.

Gorbov, V. I. Myasnikov and V. I. Yazdovskiy, 1963) defined the given state as analogous to that which exists prior to launch. Under conditions of isolation, according to the opinion of F. D. Gorbov, V. I. Myasnikov and V. I. Yazdovskiy, a state of fatigue develops. Graybiel and Clark (1961), M. B. Umarov (1962) and Sanford et al. (1962) also speak of the development of fatigue.

We find a similar case in the description of experiments with strict isolation performed by the French investigators Jonekcheere, Ewrard and Henrotte (1959). The subjects were given instructions to regulate the content of the atmosphere. In proportion to the extent of the experiment, the appearance of signs of fatigue and /47 an anxious condition were observed with the change in the content of the air (subjectively it seemed to the subjects that the percentage of carbon dioxide increased, although objectively it remained normal).

Many investigators noted significant changes in the emotional sphere of subjects in SD experiments: the appearance of varying degrees of apathy, melancholy, anxiety and fear (Heron, 1957; Sanford et al., 1962, and others).

Sometimes, apathy and dulled consciousness of the subjects become so profound that one of the most important instincts is destroyed--the instinct of self-preservation--and the person contemplates suicide (Chunningham, 1960).

The serious psychological disorders in subjects noted above, which is discussed by the foreign authors, evidently are related to the excessive burden of the severe experimental conditions on the physiology of the subjects. Here it is not only a matter of the action of isolation and sensory deprivation factors, but also a number of supplementary factors complicating the circumstances of the experiment (restraint with straps, plaster casts, uncomfortable postures, occasional painful sensations, etc.). There is also the undoubted significance of the subject's lack of conscious motivation for behavior in similar experiments which do not appear to be a true model of human life and work conditions. Relying upon experiments with extremely strict isolation, not characteristic of actual space flights, resulted in a situation where many subjects actually found themselves on the border of psychic disorders. Americal psychologists began to attribute excessive significance to the isolation factor in space flights (Lilly 1960; Dunnenberg, Morton 1962, and others). Their articles indicate that terror and fear of alienation from the Earth will be a decisive factor on an interplanetary flight.

Experiments were carried out in this plane by the American, Lilly (1956), who placed subjects in a tank of warm water to simulate weightlessness; the subjects wore masks for isolation from light and sound. Under such conditions, psychic activity became quickly disoriented and visual hallucinations began.

American scientists, having described numerous hallucinations during a long isolation of healthy people, evidently broadened the concept of hallucination, including in it several forms of sensory illusion and eidetic imaginings. As an example of inclusion of eidetic imaginings, hallucination can serve to illustrate the statement of one of the American subjects, who spoke in this way about his feelings: "I saw a rattlesnake, but fortunately I understood that it was unreal." However, the investigator Lilly (1956) still regarded this situation as if it were a hallucination. Such sensory illusions usually appeared only to those people who had no way of occupying themselves during hours which were not regulated by a program and did not appear at all when they were performing tasks. /48

Experiments on the limitation of stimuli and conditions of isolation carried out by Soviet scientists showed that a healthy person with great willpower can remain in a soundproof chamber for an extended period of time without any psychic changes threatening the condition of his health. The various specific sensory illusions which appear are not of a morbid nature. This form of sensory illusion (pseudopathological phenomena) pertains to illusions associated with incorrect perception of stimuli, the information characteristic of which is insufficient (O. N. Kuznetsov and V. I. Lebedev, 1965). The illusions themselves do not appear to be a sign of psychic disease and often are encountered in healthy persons, especially in those instances when something interferes with the distinct perception of visual and auditory images; for example, poor lighting. Baseline psychological status, fatigue, distraction, states of expectation and fear are of great significance.

O. N. Kuznetsov and V. I. Lebedev (1965) in describing the presence of illusions involving recognition errors in subjects under investigation in the soundproof chamber as a consequence of insufficient information, of a feeling of the extraneous presence of eidetic images, ideas of relationship and over evaluations, do not consider these phenomena to be pathological, and propose calling them pseudopsychopathological. According to the data of F. D. Gorbov, V. I. Myasnikov et al. (1962), psychopathological phenomena were absent in the experiments of Soviet astronauts in a soundproof /49
chamber.

Soviet scientists assume that the isolation factor must be studied in conformity with conditions which can occur on space flights. In this regard, the most important factor appears to be that a person believe in the necessity of the work which he is to accomplish, and that he have a clear conception of the objects of a given experiment. Each experiment in the soundproof chamber is a moral and volitional examination for future astronauts, which prepares them for the performance of complex tasks.

In the work of American investigators, in particular Heron (1957), it was noted that SD has a destructive influence on the capacity for work and on goal-orientedness, and often occasions refusals to stay longer under conditions of isolation as a consequence of the development of boredom. Insofar as boredom was viewed as a negative phenomenon, this psychic condition received the designation "Enemy No. 1" in the papers of several foreign authors.

Henry (1958, 1961) and Hebb (1959) indicate the destructive influence of boredom. These same authors note the development of a condition of depression and apathy, and also the rise of introversion and emotional instability. It is also often noted that the appearance of the feeling of euphoria occurs among the subjects, evidencing a lowering of the control of part of the cerebral cortex over subcortical functions.

The state of euphoria arises before the end of the experiment or right after it, and is characterized by intense elation out of proportion to situations, when the subjective evaluation does not correspond to the objective worsening of functional conditions of the organism (Van Wulften-Palthe, 1951; Sanford, Silverman, 1962; et al.).

According to M. B. Umarov (1962), euphoria during the experimental process disturbed sleep and hindered the restorative processes of the nervous system. M. A. Gerd (1963) and N. Ye. Panferov (1964) noted the appearance of euphoria at the end of their experiments, despite the fact that during the course of the experiments a condition of apathy was predominant.

Gerathewohl (1959), Ewrard, Henrotte, Jonekcheere (1959), N.A. /50
Agadzhanyan and A. G. Kuznetsov (1962) report a worsening of intellectual capabilities during a long stay in the soundproof chamber. Bexton, Heron and Scotte (1954) described instances when subjects lost the ability to think systematically and productively; so-called clean periods set in.

All these phenomena do not tell about the capacity for work. Chunningham (1960) noted that it was chiefly the qualitative facet of work activity that suffered, while psychological and physiological changes were manifested to a lesser degree as the complexity of the assigned experimental tasks increased, because of increased interest in the performance thereof. Ewrard (1958) and Ewrard, Henrotte and Jonekcheere (1959) discovered an elevation of vagal tonus because of the development of fatigue as a consequence of the disturbance of sleep and the presence of discomfort.

In all these experiments with severe SD, significant autonomic reactions were noticed: frequency of pulse, a sharp rise in the adrenalin in the blood, perspiration, worsening of appetite, etc.

Many authors also noted a distortion of the sense of time and other illusory perceptions related to the loss of adequate reactions during severe isolation in soundproof chamber experiments

(Henry and Ruff, 1961; Chunningham, 1960; B. A. Dushkov and F. B. Kosmolinskiy, 1966).

Despite the established opinion that time "stretches out endlessly" in the absence of a flow of new impressions, a number of investigators have noticed the reverse phenomenom. In this regard the experiment of the French speleologist Michel Sifre (1962) is interesting: he lowered himself underground to a depth of 130 m in the Scarson Ice Cave and spent more than 1500 hours--62 days--there with the aim of studying influence of extended isolation and absence of communication with the external world on the sense of time. Inasmuch as the observation of changes in day and night were impossible under these conditions, orientation in time was disturbed very quickly. For Sifree "the bond of time fell apart". After 40 days, it seemed to him that only 25 days had passed. After the experiment finished, he announced that he had not suspected that the end was so near. The same thing was noted by the speleologists Jose Lores (1965), who spent 3 months in the Bigneron cave, and Antoine Senni (1965), who spent 125 days in the Olivier cave. Thus, when on April 2 Senni was informed that the end of the experiment /51 was approaching he was quite astonished, because by his count it was only the 6th of February.

The Psychophysiological Mechanism of Changes During SD

A number of authors maintained the standpoint that the basis of the mechanism of psychological changes under the action of SD appears to be the rise of inhibitory processes in the cerebral cortex, depending on the sensory understress of the cortex itself as well as on the lowering of the flow of afferent impulses coming into the cortex from the subcortex and from the reticular formation of the brain stem (Henry, 1958; Hebb, 1958; Heron, 1957; Miller, 1958).

I. P. Pavlov considered that the weakening or exclusion of afferent impulses leads to the appearance of passive inhibition. Analyzing the data from the investigation of V. S. Galkin (1932) on the exclusion of the functions of several analysors in dogs, I. P. Pavlov indicated that under these conditions a lowering of the tonus, a weakening of the excitatory process, a mitigating appearance and broadening of inhibition in the cerebral cortex occur. Experimental study of the visual analysor under conditions of lowered illumination made possible the assumption, expressed by A. V. Lebedinskiy (1958), that under conditions of a lower tonus state in the cortex, the development of the inhibitory process during a stay in darkness will be especially sharply expressed. In experiments on animals, A. V. Lebedinskiy noted the destruction of the balance between motor and autonomic components during exposure to darkness. He sees the reason for autonomic response amplification in the appearance and irradiation of the inhibitory process in the cerebral cortex.

Henry (1958, 1961) explained the appearance of psychopathological symptoms in isolation as the destruction of the balance between internal information and information from the sense organs, registering everything taking place during sleep. Higher nerve integration is destroyed. Internal information becomes predominant, as a result of which hallucinations arise with nervous dreams and other phenomena.

It is possible that for sensory isolation, the development of passive inhibition against a background of lowered excitability of the nerve cell is characteristic, for according to the data of a number of authors, sensitivity thresholds appeared to be raised when electrophysiological methods are used (Heron, 1958). /52

Many foreign investigators assume that sensory adaptation exists with the aid of reticular formation (Miller, 1960; Megun, 1962). Under conditions of sensory isolation, when the reticular system lacks a sensory flow, it falls into an unusual situation and adapts to it as far as the accumulated reservoir of information in the subcortex will allow (the subject voices numerous complaints about an unusual flow of impressions of the past with which he cannot cope). The weakening of the usual background of stimuli and also the removal of unusually strong or unusually weak stimuli from sensory surroundings not only develop the inhibitor process in the central nervous system, but also give rise to a group of reactions, especially cortical ones, of an excitory character which act as if to compensate for the lack of stimuli. In addition, there is the possibility of viewing SD as a peculiar type of stimulus insofar as the experiments have shown that reactions to SD are completely comparable to reactions to separate specific stimuli and to sensory overstresses (Hahna, 1962).

The feeling of alienation, fear, and the appearance of illusions as to the position of the body in space Hebb (1958) associates with the excitation of the lower and medial surfaces of the temporal lobe of the brain. Hahna (1962) considers that not only the temporal lobe takes part in this, but also the visceral part of the brain and the hypothalamus. This same investigator proposes the theory concerning overexcitation of the parasympathetic nervous system up to the point of heart arrest and diastole during fear.

Consequently, isolation and SD bring on complex physiological reactions in the human organism which must be viewed from all sides insofar as possible. In this light Ewrard (1958) justifiably wrote, in his report "Conditions For Persons in an Interplanetary Ship", that "usually the mechanisms of a person's adaptation to conditions /53
of isolation and of a stay in limited space were viewed from a purely psychological point of view. In actuality they appear to be more complex and rest upon neurological and endocrine substrata." Strong or repeated strain may lead to the extinction of adaptation and to a failure of several physiological systems.

During SD a system of protective reactions acts on various levels (the total organism, the nervous system, the organs, the cells); these are viewed as a struggle of living organisms for information (Miller, 1958). Several experiments in the adaptation of an organism to SD attest to the fact that this factor is biologically significant in animal life. Evidently, the higher the organism stands on the evolutionary scale, the more difficult it is for it to adapt to SD. According to the opinion of Miller, the more complex the "living system", the more information it demands for its "nutrition".

Thus, sensory isolation as a result of the lack of contact with people and the external world and of little motor activity elicits fatigue, strain and a condition of diffuse inhibition which leads to physiological and autonomic changes in the organism; this in turn leads to a lowering of the capacity for work, a loss of awareness, etc.--in other words, to the lowering of the possibility for the reception of information by that very organism.

Hence, the understandable importance of finding a solution to the problem of sensory insufficiency, for combatting the consequences of the influence of SD is a battle to increase the work capacity and the work reliability of the whole system.

Prophylaxis of the Influence of SD Upon the Human Organism

One of the decisive factors in this regard appears to be the organization of internal stimuli: interest in the work process, variety in the form of work, sufficient degree of work, definite level of complexity of tasks and perhaps refusal to completely automate several processes (Henry, 1961; Thomas, John, 1960; Yu. K. Dem'yanenko, 1962).

Ruff (1959) proposes working out the automatism of reactions, /54
but with interesting tasks. The intellect itself is, in his opinion, an effective compensation for sensory insufficiency. The intellectual fund of the subject (his mind) can organize his own thoughts and ideas. Even Heron (1957) indicates the importance of this factor.

The same type of concept is found in the work of Chunningham (1960), who considers that the only salvation from the development of personality dissolution under the conditions of isolation is the possibility of being occupied with some kind of activity, on the condition that it is interesting and goal-oriented. Chunningham recalls the case of Dr. Bohn's 7-year isolation in a deep cave. His psychological balance was maintained owing to correctly organized and goal-oriented activity.

Ruff (1961) and Chunningham (1960) also note that the intellectuality and occupation of persons in any kind of activity characterized by personal interest and goal-orientedness impedes the appearance of hallucination. Experimental data attested to the fact that willful, goal-oriented people are able, under the conditions of isolation, to preserve and even to elevate the indices of intellectual work capacity for a sufficiently extensive length of time (Heron, 1957; Graybiel and Clark, 1961; Ruff, 1959; Henry, 1958; and others).

In special literature, the role of motivation and the processes of will in human activity is broadly illuminated. In their papers, Ewrard and Eddowes (1957), Henry (1958) and others indicate the importance of motivation and of moral qualities as factors providing the best indices of activity. Psychic tone and motivation influence the reaction of an individual and his inter-relationship with other members of the isolated group or crew. Henry considers ineffectiveness and carelessness of actions to be the chief consequences of boredom. In order that the readiness of astronauts for immediate actions in critical situations be maintained at a high level, it is necessary to vary their work during the course of a prolonged period of flight (Chunningham 1960, M. B. Umarov 1962, et al.).

We find an example of good isolation tolerance in the work of /55
Henry (1961) in connection with an analysis of the influence of motivation, and also the organization of interesting and varied activity in the personnel make-up of the submarine Nautilus during an extended, autonomous journey.

The experiments of Hebb (1958) on isolation showed that the visual analysor must be in continual activity (a change in lighting and chromatic scale); otherwise it loses the ability to apprehend a stable form. Evidently, this can have significance for the conditions of space flight in working with instruments at the control panel, when extended stress of concentration or attention occurs against a background of general sensory limitation and of circumstantial monotony, which can lead to definite errors in the functions of the analysor, an overstressing of the visual with an understressing of the auditory, the muscular, etc. Markworth (1962) also emphasizes the division of normal work of the visual organ and of a sufficient level of interest (awareness). In working with apparatus, especially with an oscillograph indicator, in his opinion visual fatigue begins after a short period of time (30 minutes). For prophalaxis of fatigue and for elevation of vigilance, he proposed using some pharmacological means (benzedrine).

Sanford et al. (1962), for the creation of a favorable emotional background and functional abilities of the central nervous system, also recommends several pharmacological means of stimulation such as benzedrine or amphetamine.

The emotional overtones of the activity of the astronauts have great importance. As is well known, the suppression of emotional tonus leads to a lowering of the work capacity (Corkindale, 1961; Hahna, 1962; M. B. Umarov, 1962). The elevation of the emotional tonus and of the capacity for work consequently is achieved by means of physical exercises (Ruff, 1961; T. T. Dzhamgarov, 1962; M. B. Umarov, 1962; A. B. Korobkov, 1964; V. L. Marishchuk, 1966). Ruff (1961) considers that bombardment by means of proprioceptive impulses and physical exercise supports the tonus of the cerebral cortex at the proper degree, considering this phenomena as a factor /56 compensating for insufficient afferent stimuli.

Ewrard and Eddowes (1961), relying upon data received from Beeton and Gerathewohl (1959) in a study of the action of isolation, came to the conclusion that the construction of a space cabin corresponding to the physiological demands of a person and to his individual needs can decrease the influence of isolation.

In order to deal with the disturbance of psychological functions as a result of a reduction of the informational level of the cerebral cortex, an astronaut must have a concept of these functions to understand the reason and the cause of their production. Hence the necessity of preparatory instruction, which Henry (1961) supports.

Upon solving the problems of future prolonged flights, a question as serious as the composition of crews of multipassenger space vehicles arises on logical grounds. The important problem of human psychology under the conditions of extended existence in a small group comes up. Experiments simulating space flights have shown that location in a limited space entails in itself a heightened excitability, which in particular circumstances is translated into hostility. The presence of two or more astronauts in a cabin may negatively reflect upon work capacity, which evidently will be in directly proportion to interdependency (Gross and Svab, 1965).

From this stems the necessity for a careful study of the question "of psychological compatability" under conditions of occupation in a limited space of small volume? Abroad (mainly in the USA) much attention has been given to this question with the goal of working out the demands for the characterological peculiarities of individual members of the crew, so that its composition will involve the lowest potential possible for serious conflicts. In the report of F. D. Gorbov and F. P. Kosmolinskiy the problems of the importance of psychological compatability are discussed.

In conclusion, it must be noted that the problem of the influence of isolation and SD on the human organism is very serious. During prolonged space flights, in one way or another, the negative sides of a person or a group of people in an enclosed space of /57 small volume can appear. This is why it is necessary to have further study devoted to the investigation of the design of a whole system of measures and methods which will block the development of undesirable physiological changes.

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INFLUENCES ON THE HUMAN ORGANISM OF ALTERED AFFERENTATION

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ABSTRACT: Among the factors acting on the astronaut during prolonged space flights, variations between sensory understressing and sensory overstressing have the greatest significance. An informational overload is shown to affect the organism as detrimentally as the opposite phenomenon (sensory deprivation). Several solutions to the problem of overcoming these difficulties are discussed, including total organization and control of the interior arrangement of the spaceship, ordering of a work and rest regimen for the crew and preflight training.

The problem of man's adaptation to the conditions of an extended space flight includes the question of the interrelationships of the organism's afferent systems and a changed and unaccustomed environment. /59

Under the conditions of space flight, one can expect an alternate effect of changed afferentation, of sensory understressing and of sensory overstressing on the organism (sensory deprivation and sensory bombardment, according to the terminology of Miller, 1958).

The change in the stimuli "spectrum" under the conditions of space flight leads to a fluctuation of stress on the analysors of the nervous system. The stress on the visual, auditory, muscle-joint and other analysors is diminished, which permits one to speak of sensory insufficiency or understressing (deprivation). In some circumstances, under special or complex conditions of flight, the stress on the analysor systems can be elevated, and then one speaks of sensory overloads.

According to the opinion of Miller (1958), the adaptation of an organism to changing life conditions includes not only thermodynamic balance, but also balance between incoming and outgoing information. Hence the conclusion that any essential disturbance in the regimen of the receipt of information can lead to serious functional disorders in the organism.

It is supposed that among the factors influencing the organism on extended space flights, the greatest individual importance will belong to the so-called "situation" factors, in particular isolation, uniformity and monotony of stimuli, and especially sensory insufficiency. Leaving aside the other "situation" factors, which have undoubted psychological significance for space flights (feeling of separation from Earth, change in spatial orientation, lack of feeling of support, etc.), we will give our attention to sensory deprivation (sensory understressing), as well as to a synthetic factor which has a large influence on changes in the general functional condition of the organism and of the structure of the dynamic stereotype of higher nervous activity. /60

On extended space flights, a person can become exposed to various forms of impoverishment of sensory stimuli depending upon a number of reasons. The following can be indicated:

(1) Isolation of an individual or of a group of persons (social isolation); i.e., lack of contact with the external world and other people, accompanied by sharp reductions of external (exteroceptive) afferentation.

(2) Exposure to a confined space limited in volume dictates little motor activity (hypokinesis or hypodynamia), and secondly, a lessening of internal (introceptive) chiefly proprioceptive afferentation.

(3) Weightlessness causing a change in the character of motor reactions, as a result of sharp diminution of the flow of afferent impulse intervals.

(4) A general lowering of the flow of external afferentation, i.e., scarcity of visual, auditory and other stimuli, due to the extended action upon the organism of a uniform and limited sphere of stimuli (monotony of the situation).

Numerous theoretical and experimental works have been dedicated to the problem of sensory insufficiency, in which the investigators concentrate on significant changes in physical activity on the part of subjects observed in a restricted space of small volume. Thus, under the conditions of standard isolation general physiological tonus lowered, sleep was disturbed, the functions of attention changed, the sensory-motor reactions worsened and a condition of nervous tension and, sometimes, apathy arose, etc. (Herron, Bexton, Hebb, 1953; Lilly, 1956; Hebb, 1958; Ruff, 1961; Hahna, 1962; Sanford, Silverman and Shmavonian, 1962; F. D. Gorbov, V. I. Myasnikov, and V. I. Yazdovskiy, 1963; V. I. Myasnikov, 1964, and others).[1]

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[1] These questions were illuminated in detail in a survey article by F. T. Kosmolinskiy and Z. D. Shcherbina in the pages of the present collection.

However, one can hardly expect that under the conditions of an actual space flight, in the presence of carefully expressed motivation and behavior of the astronauts (under the current system /61 for their selection and conditioning), such serious pathological situations as psychic depression, hallucinations and even the loss of personality could arise, as mentioned by several foreign investigators on the basis of their experimental data (Herron, 1957; Hauty, 1960; Horowitz, 1964, and others).

Sensory understressing or "sensory starvation" can lead to a lowering of the work capacity and functional work vigilance ("operative attention"). Already during the Fifties, under the conditions of air flights, the appearance of diffuse somniferous inhibition had been noticed among pilots engaged in the test operation of airplanes (F. P. Kosmolinskiy, 1954). The apparent influence of circumstantial monotony was present (monotony of stimuli and diminution in the flow of external afferentation). The introduction of automation into aircraft piloting attracted the attention of specialists to this question (V. A. Popov, A. M. Pokovskiy and E. I. Ivan'kov).

In investigations in soundproof chambers of a stay prolonged for 10-15 days, carried out by F. D. Gorbov, B. I. Myasnikov and V. I. Yazdovskiy (1963), one noted the development among the subjects of complex physical changes depending, in the opinion of the authors, on the limitation of external afferentation. During the first days of the experiments, strong elimination in the urine of 17-ketosteroids was noted, evidencing the development of emotional strain in the subject. During the following days, the authors noted a depression of the adrenal glands' functions and the development of appearances of fatigue. Uniformity of the surrounding environment, poverty of external impressions and isolation were introduced into the experiment as factors having a self-sufficing value as conditions and causes of the development of strain and fatigue.

Simultaneously with studies on questions of the influence of external afferentation insufficiency on the organism, numerous investigations were carried out on the influence of internal afferentation insufficiency, depending upon a change in gravitation (weightlessness) and the limitation of mobility under the conditions of a stay in restricted quarters (hypodynamia). Our astronauts as well as American astronauts, during orbital flights of extended duration, were in a reclining position, and the work operations /62 they performed did not demand great physical efforts and active position shifts. These circumstances led to a lowering of the astronauts' general functional tonus (I. M. Arzhenov, A. V. Beredovkin et al., 1966; I. M. Arzhenov, I. I. Aryanov, V. A. Baturenko, D. V. Buyanov et al., 1966). However, under the conditions of an actual space flight, the astronauts are influenced by a complex of extreme stimuli. Therefore, there is a natural tendency for investigators to examine the isolated influence of the extended immobility factor on the human organism. The works of Graveline (1960), Yu. V. Vanyushina (1963), L. I. Kakurine et al. (1963), Lubek and Wilgosh (1963) and others proceeded along this line.

L. I. Kakurin and V. S. Katkovskiy et al. (1963) chose as an experimental model a strict confinement to bed on a person who remained in the horizontal position for 20 days. As the authors noted, two factors of this experiment, hypokinesis and lowering of the hydrostatic pressure of the blood, appeared to be the cause of possible confusion in the function of the motor apparatus and in the circulatory and respiratory systems.

Analyzing the numerous literary sources dealing with the problem of informational biological stresses, we come to the conclusion that in addition to the sufficiently basic solution to questions of the influence of sensory deprivation, the questions of sensory overload under conditions of space flight simulation remain less well illuminated. Moreover, in certain stages of flight, the astronauts doubtless will encounter these phenomena, for example while performing radio communications with Earth and repair work, special scientific investigations, the docking of space ships, and also during various complex and emergency situations. For example, the investigations of I. N. Kanyshev (1963) show how there can be large stresses on only the visual analysor in work at the control panel with numerous gauges. In studying the pecularities of visual information during instrument flight on a flight trainer, the author established that during separate periods of the flight, the frequency of glancing from instrument to instrument reached 150 and even 200 motions per minute; i.e., on the average the pilot observed three instruments per second. These data indicate the pilot's great concentration of attention and the undoubted deficiet of time for his work. A somewhat similar situation perhaps exists with astronauts during the active periods of a flight. It is necessary to bear in mind that an astronaut's daily work production under the conditions of a deficit of time creates a sensory overload which, as a rule, will be added to the already formed condition of a lowered functional tonus, resulting in an extension of the sensory underload. It is doubtless of interest to investigators to study the nature of human reactions under these conditions involving a sharp disparity in sensory information. But to create a model of such a situation is not an easy task. /63

However, aviation practice offers us several possibilities for the realization of such a situation. Thus, we (F. P. Kosmolinskiy, S. E. Comshalyuk, N. A. Federov and I. N. Khazen, 1963; F. P. Kosmolinskiy, 1963, 1964) observed crews who completed one of the most complex tasks in flying--missions involving in-flight refueling. In these flights the moment of refueling, demanding a high level of attention and great operator skill, generally comes at a period when the condition of the pilot, having flown the airplane for many hours with the aid of the automatic pilot, is that of reduced physiological calm. A sharp differential in the informational load arises. This situation, it seems to us, turns the given aspect of the aviational task into a kind of model for similar situations in space flight (for example, the docking of space ships).

Thus, we do not have in mind the production of concrete activity and of motor reactions of an astronaut,[2] but rather the imitation of complex psychophysiological strain under conditions of surplus information. In these investigations, attention was directed towards the presence of a great peculiarity in the condition /64 and the conduct of pilots during the refueling operation.

The refueling operation demands great precision on the part of the pilot, calling for exceptional motor coordination, concentration and attention. Under these conditions of heightened sensory stresses, a great physiological strain is noted both subjectively and objectively. The basic physiological functions change sharply. The presence of all components of emotional (sthenic) strain exist (physic excitation, autonomic dysfunctions, characteristic posture changes, mimicking, etc.). The frequency of heart contractions approaches extreme limits (up to 160-186 beats per minute), and the respiratory rate also increases (up to 40-54 times per minute). Perspiration increases sharply (the water loss approached 5-7% of the body weight of a pilot), as does heat formation (body temperature rose by .7 to 1.2°). Extensive biochemical changes were noted: the elimination of 17-ketosteroids by the organism sharply increased (sometimes 6-8 times above normal) as did that of ascorbic acid (10-20 times and even more, exceeding the original level), which indicates a condition of stress (I. G. Dlusskaya, F. P. Kosmolinskiy, N. A. Federov, 1963; F. P. Kosmolinskiy and F. E. Komshalyuk, 1963).

A physiological analysis of these data leads one to the conclusion that such intense emotional strain on a pilot flying an airplane depends upon a number of causes. Among these, tension has great significance. It appears in pilots as a consequence of the constriction of the spatial field: the immense expanse of the ocean of air suddenly becomes amazingly crowded because of the proximity of the fueling aircraft (the tanker). Moreover, the operation of docking the aircraft brings on a definite psychological difficulty which entails uniting two types of activity: the usual

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[2] Similar investigations were carried out by Simons and Walk (1965), who studied the motor reactions of subjects imitating the process of transfer from one spaceship to another, using a weightlessness tank located in the fuselage of an airplane flying a Kepler parabola.

piloting of the aircraft on the basis of already solidly worked out automatic habits, and the necessity for the pilot to perform the additional, relatively new and less familiar task of refueling, which involves a great load on the system of analysors. The significant predominance of the psychological orientation for the fulfillment of this new and consequently unstrengthened activity stereotype turns out to be the dominating one, which acts as if to suppress the reinforced piloting habits and thus gives rise to difficult neuropsychic condition. The experiments which have been carried out permit one to prescribe a number of prophylactic measures directed toward the elevation of physiological stability /65 under conditions of extended activity involving sensory overload or sensory deprivation.

In connection with this, both sensory underload and sensory overload lead, in the final analysis, to physiological strain and fatigue; a problem which leads first of all to the necessity for maintaining a high level of functional possibilities for the organism's abilities.

First there is the matter of developing the optimal regimens of work and rest conforming to the concrete conditions and tasks of space flights.

A special motor activity regimen for the maintenance of the necessary physiological tonus, capacity for work and the stability of a number of psychological functions appears to be an important prophylactic measure. This regimen includes a general physical stress and special physical exercises performed several times a day (T. T. Dzhamgarov, I. I. Petrushevskiy, 1961, and others).

A. V. Korobkov (1963) proposes, as a general principle, the elevation of an organism's stability in the presence of factors of the external environment by means of a regimen of motor activity. This regimen is especially necessary in situations of isolation and of sensory deprivation. Active motor activity, static efforts and elevated tonus of muscles elicit a large flow of sensory information which, by the reflex mechanism, promotes the completion and stability of effective high nervous activity, (atrophic influence on the various tissues, activating the gland function of internal secretion, having a positive influence on the stability of the vestibular apparatus, etc.). A. V. Korobkov views a regimen of motor activity as a means for preservation of the terrestrial information "spectrum" and, on this basis, the means to provide the optimal state of the biological milieu of the organism and of psychic activity and mental capacity for work.

The organization of the entire flow of circumstances and character of life on the ship appears to be one of the means for the /66 maintenance of external sensory information at a sufficient level in the cabin of a space ship. A complex of questions has bearing here, several of which go into serious scientific problems and perspectives: the inter-relationship of crew members (questions of group psychology, stimulation of the secondary signaling system of activity); the organization of work at the control panel (questions of the psychology of work and of engineering psychology); creation of the necessary level of visual stimuli; organization of the interior and its periodic change; that of auditory stimuli (a system of musical programs); etc. G. K. Mikushkin (1966) proposes the idea of using the mechanism of inter-relationship of the analysors in that some of them may be stimulated by stimulating others. In his opinion, the "functional atrophy" of muscular analysor under conditions of weightlessness can be compensated for to a certain degree by strengthening the functions of the visual and auditory analysors. This may be achieved, on the one hand, by training astronauts on Earth, and on the other hand by simulating, in the cabin of the spaceship, the "accustomed" terrestrial conditions relative to space and time. In this respect, it appears necessary in particular to elaborate the astronauts' reactions on the basis of visual, auditory and vestibular analysors having stable forms, which lie at the basis of space and time perception and of the perception of the spatial position of the body.

Great significance should be given to the possibility of changing certain physiological stimuli on long space flights with the aim of supporting a sufficient level of work capacity and psychological activity. Thus, for example, a supplementary dispensing of pharmacodynamic doses of certain water-soluble vitamins (ascorbic acid, 300 mg; vitamin P, up to 150 mg; vitamin B_1, 25 mg; para-aminobenzoic acid (PABA) 25 mg; and others) with glucose gives good results in practical aviation (elevation of the general physiological tonus and a lowering of nervous tension in pilots who are performing complicated flights) (F. P. Kosmolinskiy, I. D. Dlusskaya et al., 1963).

In order to overcome the phenomena of tension and of emotional /67 stability at the moment of sensory overstressing, several authors propose specially directed conditioning. Thus, V. L. Narishchuk proposes teaching the skill of self-control of one's own emotional condition to external manifestations of emotion. In order to do this, it is necessary to know how to determine if a constraint of involuntary muscle tension exists; how to control rhythm and depth of breathing; how to check the pulse during conditions of emotional excitement; how to develop special habits for a more complete voluntary relaxation of the muscles and how to establish a calm respiratory rhythm. It is possible to elevate emotional stability as a means of forming special habits of self-control over external manifestations of emotion, and, with the help of these habits, to overcome them.

In conclusion, it is necessary to note the necessity of more extensive investigations in the area of the study of changes in the functional condition of an organism under the influence of informational overload and sensory deprivation, and also where they act alternately. It appears important to have further investigations of new methodological procedures in these experiments, the creation of models of the conditions of sensory overload, and also the alternation of influences of stresses of various natures on the organism under natural conditions, as well as under conditions simulating extended space flights.

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PRINCIPLES AND MEANS OF INVESTIGATION OF PROBLEMS OF DAYS IN SPACE

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ABSTRACT: The various factors influencing the possible organizations of daily periodicity under space flight conditions are discussed. Suggestions are made as to the need for further investigations relating to the organization of the space day.

Among vital problems of space medicine is included the problem /68 of the organization of work and rest of astronauts, the regimen of their life activity on board a spaceship and on orbital stations, and, in the future, on other heavenly bodies, first of all on the Moon. The organization of a man's life in space, in the first /69 place, requires the foundation of a more rational life rhythm: changes in the periods of being awake and resting which, under the work conditions, correspond to periods of various intensities of illumination; i.e., to the periods of the terrestrial day: day and night.

At the beginning of the day, the human organism reaches a condition of operative preparedness. The daylight period is the time of greatest productivity of human activity; towards night, the organism undergoes functional restoration providing valuable rest. The beginning of day and night have been turned for us into unique signal stimuli, and the process of setting our organism to work and rest has all the features of a complex conditioned reflex. Analyzing the phenomenon of the daily periodicity of physiological functions on the basis of facts obtained in the experiments of O.P. Shcherbakova and K. M. Bykov (1954), the conclusion is made that periodic changes of these functions have as their basis temporary neural bonds, conditioned reflexes formed as a result of a combination of the whole situation in which the action of impulses is felt, which defines the daily periodicity, with the definite state of the lower autonomic centers which act on the level of a number of physiological functions. The strength of such conditioned reflexes, with all other conditions being equal, as a rule proves to be very considerable. The usual change of day and night "has entered into our habits so much that our physiological and psychological stability is, to a certain degree, dependent upon this change" (K. M. Bykov, 1954).

It is precisely for this reason that the restructuring of daily rhythm, especially in the first phase of such a restructuring, leads to a lowering of the work capacity and to a worsening of the general condition of the person. Thus, in particular, it is known that even a 12-hour flight on a jet airplane at a speed of 900 km/hr leads to a change in the physiological rhythm, elicited by the change of day and night.

In space, the organization of a person's diurnal rhythm demands serious preparatory investigations. The basis of the concept, in view of which the fundamental principles and means of investigations of the problem of the space day are considered, consists of the /70 hypothese that our usual terrestrial, i.e., 24-hour, day is the optimal solution to this problem, in particular, under conditions of a comparatively short stay in space. Such a point of view is expressed by a number of investigators. It is just for this reason that the first problem is the question of those conditions of existence which (at least at the current stage in the conquest of space) exclude the possibility for the construction of a terrestrial rhythm of a day in space.

The most important of these conditions are the following.

(1) The particular characteristics of the professional activity of astronauts. This activity is characterized by a pronounced monotony, by uniformity and by unavoidable lowering of operative vigilance, more pronounced when all systems of the spacecraft work reliably and smoothly. The function of vigilance suffers especially from the accumulated effects of fatigue (Hauty, 1959). The lowering of operative vigilance limits the length of the astronaut's watch, and consequently creates a supplementary limiting condition on the organization of the space day. Evidently the duration of uninterrupted monitoring under the conditions of space flight cannot be more than 4 hours. The investigation of Mervill Jones (1960) established that, at the time of highly intensive and extended flights, the normal duration of a radioman's watch is 3 hours. With a greater duration, a progressive worsening of the standards of work arises, as well as tension and irritability.

(2) Extension of the monitoring activity sequelae. Lowering of the psychological productivity of the operator takes place not only at the end of watch but also for some time after. The profile of diurnal rhythm in space is regulated by taking this consequence into consideration.

(3) The character and intensity of illumination in the cabin of spacecraft. The illumination and diurnal rhythm are related as cause and effect. The daily periodicity of life activity of a man and of many representatives of the animal and plant kingdom /71 is based on the periodicity of intensity of illumination (primarily of solar illumination). In special experiments with monkeys, O. P. Shcherbakova (1949) "alternated" day and night, systematically illuminating the cage by night and darkening it by day, and setting the feeding time at night. It resulted that by the 7th-8th day a maximum of temperature, motor activity and the highest pH in the

night. Having created two "days" and two "nights" during one astronomical day (illumination and feeding of the monkeys from 9 A.M. to 1 P.M. and from 7 P.M. to 1 A.M.), O.P. Shcherbakova recorded two periods of motor activity, two temperature maxima and two maxima in respiration rate.

When Shcherbakova illuminated the cage by night, darkened by day and fed the monkeys by day (in darkness), then the curve of physiological functions reflected the influence of illumination almost exclusively.

Aschoff (1964) showed that the intensity of illumination played a special role in establishing daily periodicity with various organisms.

It is important to emphasize that the dominating visual analysor in man and its receptor evolved under the influence of solar light. Therefore, the spectral sensitivity of the eye lies in the maximum of the spectral curve of solar energy, which led F.I. Vavilova to call the eyes "solar"; moreover, solar energy has the value of a factor which influences the metabolic processes of an organism (hence its use in medicine: heliotherapy).

(4) The particular properties of the muscular activity of astronauts. The muscular activity has a direct relation to the periodicity of the physiological functions. In the experiments of N.E. Panferova (1963, 1964), hypodynamia was accompanied by a leveling of the physiological activity of the human organism (body temperature, pulse rate, blood pressure). Such conclusions were made of the basis of analysis of physiological indices in the soundproof chamber experiments of Yu.A. Gagarin (1962).

(5) The number of members of the crew on the craft. Depending on the size of the crew, the order of the day of the astronauts can be changed in the direction of a closer approximation to an optimal regimen.

(6) The individual characteristics of the astronauts and their past experience. It is known that some people possess the ability to fall asleep and to wake up at any given moment of time. Past experience of a person (habit of mono- or multiphase sleep, "dead hours", etc.) also dictate to a degree his adaptation to an unusual daily regimen. /72

An analysis of the conditions determining the structure of regimens of work and rest for astronauts with the tasks of formulating practical recommendations for each specific actual flight does not signify, however, an exclusion of a broader scientific investigation within the limits of the problems which interest us. As the basis of such a broader investigation of problems of the space days from our point of view, it must replace a potentially fuller classification of diurnal rhythms, not connected with any concrete conditions of human existence. In order to construct this classification, we will start out from a position according to which the optimal diurnal rhythm is our customary terrestrial 24-hour rhythm. Increasing or decreasing the number of hours in these days, we will obtain an extended (25-, 26-hour etc.) or shortened (23-, 22-, 21-hour etc.) day. Any daily variance, if it is taken as unique and unchanging, over the course of a certain length of time can be called the static variant (static day). In addition to such a static variant, we must consider the so-called "migrating" or dynamic variant, whose essence amounts to the fact that each successive period of the day (e.g. the sleep period) in each instance moves away from (or approaches) the end of the preceding period (e.g. the work period). In other words, migrating days are characterized by the inconsistency of their periods: the beginning, the end, the duration characterized by such irregularity can be multidirected; i.e., in one instance there will be a constant withdrawal of the definite period (sleep) from the preceding period; in another instance an approach; in a third instance the periodic succession of withdrawal and approach. The same can take place even in regard to absolute duration of various periods of the day.

The next type of day is a mixed day: mixed days, in contrast /73
to simple days, we designate as an ordering of waking and sleeping such that, let us say, following a 12-hour day there is an 18- or 24-hour day or some other kind of day, wherein each variant of day is either used only once or is repeated any number of times. It is from such a classification that experiments must be constructed for the study of the various variants of diurnal rhythms in space. We have already noted that the optimal variants of diurnal rhythms must be considered to be the usual terrestrial variant. However, this assertion by no means signifies a denial of the possibility for a man to adapt to rhythms of existence which differ from the terrestrail one. Moreover, it is possible to consider the ability of the person to adapt to various diurnal rhythms proven. Thus, in particular in the investigations of D.I. Ivanov et al. (1963) it was shown that under the conditions of unusual diurnal rhythms (sleep from 20 hours 30 minutes to 2 hours 30 minutes and from 12 to 14 hours), the daily periodicity of basic physiological functions not only displayed less contrast, but also was distorted: the pulse rate, respiratory rate and the body temperature at the time of sleep were greater than in the waking period, which did not occur in the ordinary diurnal rhythm under other similar experimental conditions (D.I. Ivanov et al., 1963). Specialists of the Lockheed firm report a positive result of a 30-day experiment in which subjects worked 4 hours and rested 4 hours.

In his notes, G.S. Titov (1963), living under the conditions of a rhythm different from the terrestrial one (25 hours), noticed that for him the concept of day and night was eliminated to a certain degree. The restructuring of a person's diurnal rhythm is a relatively difficult and, quite often, a very slow process. Thus, particularly in the study of V.P. Solov'ev and G.M. Gambashidze (1963), data were presented of the study of the physiological functions of the night-shift workers in the Moscow subway. Even their distortion of the diurnal rhythm, which had lasted many years (work at night, sleep during the day), was nto accompanied by restructuring of the rhythm of physiological functions, the cause of which (in the authors' opinion) is poor organization of daily rest. /74

T.P. Vol'khina and R.I. Kryuk (1963) investigated the physiological functions of linotypists under conditions of three-shift work and found that, during the night shift, they always adjust their level to the time of the day and that the worst operative efficiency falls exactly at those hours; hence the conclusion that the daily periodicity influences the physiological condition of linotypists. According to the data of E.I. Brandt and O.I. Margolina (1962), a drop in the temperature of railroad workers in the night shift during the winter is more significant than in the day shift, given the same work load. Den Su I (1962) established that electrical activity in the muscles during absolute rest is greater in the daylight hours. The stability of the usual terrestrial rhythm of a person follows from the fact that under total isolation with the exclusion of all indices of time a spontaneous life rhythm, close to the 24-hour rhythm, is established in man (Aschoff, 1930, 1937).

It is necessary to emphasize that a recognition of the possibility of a man to adapt to new life rhythms does not signify any facility for concrete study of the characteristics and mechanisms of such adaptations, because the dynamics of physiological functions and various diurnal rhythms, in the majority of the projects known to us, appear as the total response of the organism to numerous experimental conditions. Thus, most frequently, astronauts or subjects of experiments are transferred to new regimens of work and rest under totally new conditions of existence: in soundproof chambers, in spacecraft simulators, in tanks, etc.

Therefore, we see the study of "space" days aim for the simplification of experimental conditions to a degree which would facilitate the possibility of registering the influence on the human organism of only one unusual factor of future life in space in each case. Thus, for example, in the first experimental stage, the subject might remain under normal conditions of life and activity, but his rhythm (i.e., the duration of periods of waking and sleeping) might be changed according to a given program. A new rhythm is superimposed (applied) on the former life style of a person. In the second stage, the influence on the subject of only new activity in /75
usual circumstances is studied: for example, the monitoring activity; then the influence of this activity in usual circumstances but in another rhythm; afterwards in a simulator of a space vehicle, first with a 24-hour rhythm and finally under conditions approximating as closely as possible the entire situation of life in space. The development and approbation of artificial stimulation of the process of human adaptation to an unusual regimen of work and rest appears to be an important task within the scope of the problems of life in space.

A program of research in this direction might include the following.

(1) A study of the effectiveness of pharmacological means which strengthen both the inhibitory and the excitory processes in the higher regions of the central nervous system, as well as facilitate a person's acquisition of a new diurnal rhythm.

(2) A study of the influence of low and altered afferentation on the rate of a person's "adaptation" to a new diurnal rhythm.

(3) A study of the influence on the rate of normalization of sleep, of artificial muscular weakening and voluntary exclusion of psychic activity.

(4) Development of methodologies and their use in studying individual characteristics of human adaptation to artificial diurnal rhythms.

Such are the most important tasks facing space medicine and psychology in the area of studying the porblems of the space day.

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THE INFLUENCE OF VARIOUS REGIMENS OF WORK AND REST ON THE FUNCTIONAL CONDITION OF A MAN DURING A LONG STAY IN A HERMETICALLY SEALED CHAMBER

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ABSTRACT: To investigate the effects of a prolonged space flight on the human organism, two experiments were conducted in which subjects were placed in a hermetically sealed chamber and their reactions were studied. As a result, the specific effects of these unusual environmental conditions and of an unaccustomed regimen of work and rest were able to be pinpointed.

In order to develop regimens of work and rest we have started from the data given in the references, which indicate that with a change in daily rhythm, the course of the basic physiological functions of the organism also changes, which is expressed in a worsening of the general condition, in changes in temperature compensation, in a lowering of the indices of activity of the cardiovascular and muscular systems, and, connected with all these, in the intellectual and physiological capacity for work. These changes are functional, and after a definite length of time the organism can adapt to new conditions. The adaptation process in a given instance will be characterized by the stabilization of the organism's functions at a new level. /76

These positions must be valid, to an equal degree, even for activity of a spacecraft crew on an extended flight. In connection with this, various regimens of life were investigated under conditions characteristic of the limitations imposed by a space flight.

The investigations were carried out using a hermetically sealed chamber, 23 m^3 in volume (free air content was 15 m^3 which had a welded metal construction.

The chamber was equipped with a place for resting (a bed), a special chair (a reclining chair) for the use of the subjects on watch, and dining and work tables necessary for the experimental apparatus and life support system (regeneration apparatus, air-conditioners, heaters, etc.).

Three subjects took part in the experiments: subject I., 30 years old; subject M., 27 years old; and subject S., 23 years old. For the first 15 hours of the experiment, the reactions of the organism under a life regimen structured by an 8-hour sleep period and a 16-hour waking period for each subject were studied (see Fig. 1).

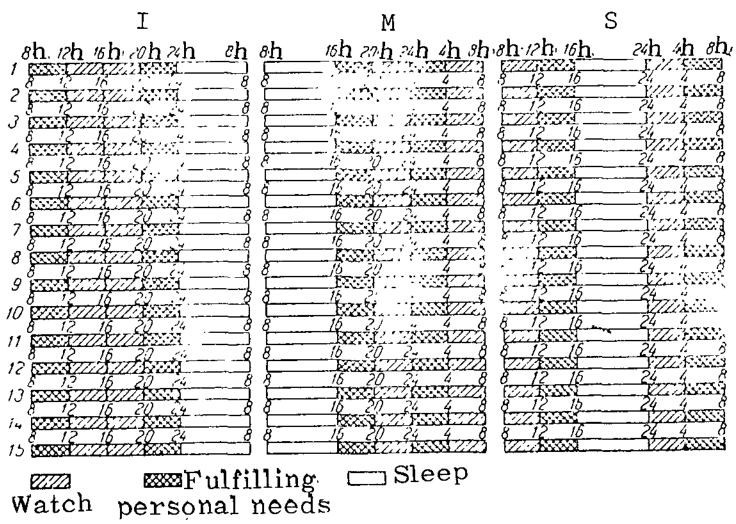

Fig. 1. Scheduling of the Periods of Sleep, Personal Functions and Watch of the Subjects in the First Experiment.

For the first subject, sleep and waking periods did not essentially differ from the normal. He slept from 12 A.M. to 8 A.M.; then for 4 hours he was occupied with tending personal needs; at noon he began to work and, with an hourly break, he remained on watch till 8 P.M., after which he rested and took care of his personal needs. /78 For the second subject, the sleep period was from 8 A.M. to 4 P.M. After sleeping, came a period for fulfilling personal needs, then watch (from 8 P.M. to midnight). Then he had another 4-hour period for taking care of personal needs, and a watch.

For the third subject, sleep was from 4 P.M. to 12 A.M.. Afterward he began a work period lasting until 4 A.M., followed until 8 A.M. by a period of rest and taking care of personal needs. From 8 A.M. to 4 P.M., periods of work, of rest and of caring for personal needs again followed. Thus, the period of waking for him, just as with the second subject was not ordinary and encompassed the hours of astronomical night.

A second 15-day experiment, with the participation of the same subjects, was carried out a month after the first experiment; i.e., after all the consequences of the first experiment had disappeared. For this experiment a regimen of work and rest was constructed in the following way: the subject slept for 6 hours, stayed on watch for the same length of time (two watches of 3 hours each), and had the same number of hours for rest and caring for personal needs (Fig. 2). Thus, the duration of three astronomical days corresponded to 4 days of the experiment; i.e., the whole experiment consisted of 5 equal 72-hour cycles.

The work activity during the watch periods of both the first and second experiments included: monitoring activity (observation of instruments at a panel, 2 hours per watch); work on reporting the results of checking the gas environment and functional organism changes; systematic recording in the log books of their observations; and muscular activity (a physical exercise program. Watches at the panel took place in a special lounging arm chair in a position corresponding to the position of an astronaut. While on watch during the so-called monitoring activity, the subject worked at a special panel. In the event signals were received at the control panel, he had to select a changing program of answering signals with the aid of 6 tumbler switches. In order to assure responsible behavior on the part of the subject working at the panel, a "punishment system" was constructed. If a signal was missed or if an error was made,

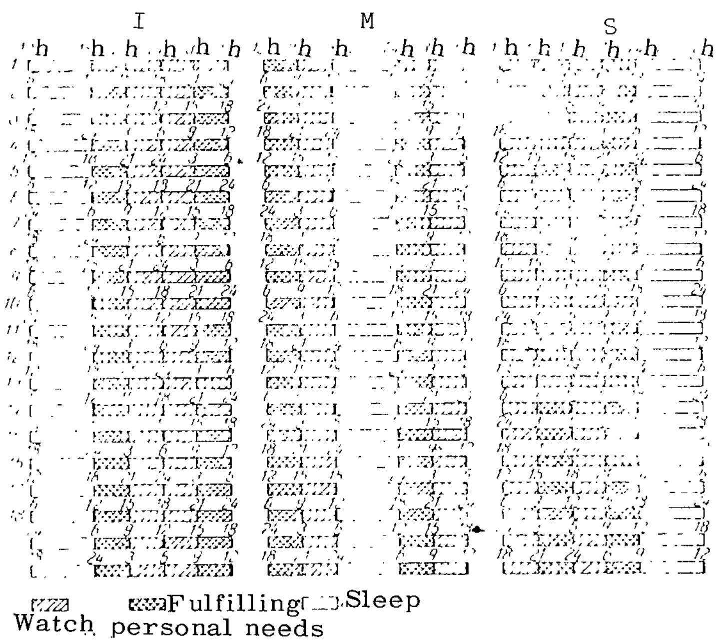

Fig. 2. Scheduling of Periods of Sleep, Fulfilling Personal Needs and Watch of the Subjects in the Second Experiment.

a tone of 105 dB automatically sounded. Turning off the siren was possible only with the aid of the two other subjects, of whom one had to interrupt his sleep and the other had to break away from whatever program had been set up for him.

During periods of caring for personal needs and rest, the subjects, aside from sanitary hygienic measures and preparation of food, occupied themselves with medical investigations, work at a bicycle ergometer, and also performed a complex of physical exercises.

Before the beginning of the experiment, the subjects underwent a complete physical examination and were declared to be healthy and suitable for participation in the experiment.

Methods of investigation. In order to evaluate regimens of work and rest, complex investigations were employed, including different methods of studying the intellectual and physical capacity for work. /80

The degree of attention of the subjects was evaluated with the aid of correction tests, which consisted of a series of printed symbols (1600), distributed on one page in groups from 3-5 symbols in each, with 40 printed symbols per line.

The subject had to cross out a specific combination of letters. The concentration of attention was judged by the number of mistakes (omissions or incorrect cross-out combinations). The time needed to complete the tests was also evaluated; that is, how quickly the subject concentrated his attention.

In the memory study, the subjects were instructed to recall a number of abstract and concrete words (20 words). The character and amount of the material produced after a certain interval of time served as a basic index of the condition of the subject's memory for the given time period.

Intellectual capacity for work and the thought process as such were studied with the aid of modified Krepelin tests, association tests, and also with a variety of blanks, through which the process of generalization and analysis were traced. In the association tests the subject was directed to respond to each word presented with a word of opposite meaning. In addition, three words were presented at once, two of which had a definite meaning-dependency; for the third word it was necessary to select a fourth which had the same relationship in meaning as the first to the second (method of parallel analogies).

The modified Krepelin test consists of 8 pairs of numerical series with 23 numbers per line. In each pair of lines, the numbers are distributed under each other. The subject had to add these in sequence and subtract this sum from the same three digit number. The result of the subtractions were written under each pair. The work time for each line was strictly limited. After 30 seconds the subject had to transfer to the following line on a signal given by the experimentor.

The speed and accuracy of subtraction (the Krepelin test), the nature of association, the adequacy and latent time of response reaction (association tests) allowed the possibility of judging the intellectual work capacity and the thought process. In both experiments, on the basis of twice daily measurements of the axillary temperature, the condition of thermal regulation was evaluated. The subjects were weighed daily.

The methods of ergography, dynamometry, investigation of coordination of movements and determinations of muscular tone were used to characterize the capacity for work and the influence of the regimen of work and rest on the fatigability of a person during his stay in the hermetically sealed chamber.

The recording of the ergographic indices was made according to the generally accepted method of working on the finger ergograph with a rhythm of 1 motion per second and a weight of 4 kg. Work was continued to the point of fatigue. In order to characterize the restorative processes, after 2 minutes of passive rest the work was repeated until fatigue. Analysis was made of the amount of work which had been accomplished until fatigue in kilogrammeters and the length and amplitude of the ergographic curve.

The strength of the right hand was determined on the finger ergograph before work, immediately after work and after 10 minutes of passive rest. Measurements were made 3 times under uniform conditions. Strength was measured before and after work on a bycycle ergograph (with a load of 600 kgm/min for 25 min.

Many investigators consider the study of motor coordination as a method which characterizes the functional condition of the motor center of the cerebral cortex. In our investigations, the precision of movements was determined by means of an instrument which registered even slight deviations of the hand's motion from the given path of the drawing, the number of mistakes, the time and the length of the traced path. In order to obtain comparative data, an account was made of the number of mistakes per unit rate.

The functional status of blood circulation system was evaluated by means of hemodynamic indices studied under analogous conditions in both experiments.

Measurements of arterial pressure and pulse rate and recordings of electrocardiograms and polycardiograms were carried out on the subjects immediately after sleep. In experiments with an 18-hour daily cycle, the data obtained were analyzed as dependent upon the /82
time of the subjects' awakening.

Investigations of the functions of external respiration were carried out for all subjects under strictly standardized conditions of basal metabolism, immediately after sleep and on an empty stomach. An inspection was carried out 3 times before, 4-5 times during the experiments, and once after them.

In the first experiment, investigations were carried out on the 2, 5, 8, 11 and 14th day where the time of the tests, as well as the time of sleep, was fixed.

In the second experiment with 18-hour cycles, investigations were carried out on the 3, 6, 9, 12th astronomical day where, although the time of sleep was shifted, the tests for each subject were fixed and were carried out at the same time. Considering that 0600 hours and 0800 hours in the morning are comparable to the usual time of investigating external respiration, it was proposed that the question of how the given function would change at other hours, in particular 0000 hours, 1600 hours and 1800 hours (Table 2), be investigated.

TABLE 2. TIME OF INVESTIGATION OF EXTERNAL RESPIRATION (HOURS OF THE DAY)

Subjects	1st Experiment, Hours	2nd Experiment, Hours
I.............	08	00
M.............	16	18
S.............	00	06

The frequency and minute-volume of respiration were studied, and tests were also carried out on the retention of breath, inspiration and expiration. Gas exchange was determined with the aid of a gas analyzer of the Belau system. Afterwards a number of secondary volumes were calculated: volume of tidal air, volume of alveolar ventilation, respiratory equivalent, coefficient of oxygen use, respiratory coefficient and base volume.

Studies were made of the nitrogen content in the daily urine (according to the Kjeldahl method). A collection of the material under investigation was taken before the experiment, during the experiment (each day) and after the end of the experiment.

Hematological investigations were carried out on each subject after he slept and on an empty stomach. The number of erythrocytes, amount of hemoglobin, number of leucocytes, and the rate of erythrocyte sedimentation were studied. The size of erythrocytes was determined and a differential white count was calculated, as was the quantity of thrombocytes and reticulocytes. /83

In the second experiment, in order to study supplementary data on the general stability of the organism, and in particular of the resistance of its tissues to the action of various factors, the osmotic resistance of erythrocytes in the peripheral blood (ORE) of the subjects was studied. This was determined before the experiment, on the 8, 11, 14th days of the experiment and after the subjects left the chamber. Each time, 5-7 parallel tests were made. ORE was defined according to the modified method of Vasilevskiy, Barasheva et al. (L.V. Serova, 1964). A concentration of sodium chloride from 0.4 to 0.85% was used.

At the time of the experiments, the microflora and the tegumental tissue were studied, and several indices of the subjects' natural immunity were investigated. The microflora of the skin of the subjects was studied by the patch method proposed by N. N. Klemparskaya and O. G. Alekseyeva (1958).

Because a study was made of the influence of bactericidal clothing on the autoflora of a person's skin from a chemical point of view (using material with which hexachlorophine was chemically bound), a study of the microflora was carried out on the open skin (internal surface of the skin of the left forearm) and on skin constantly covered by the clothing (left shoulder blade).

In order to make a more complete study of the microflora, 215 strains of staphylococcus were isolated from the internal surface of the skin at the left forearm, and 120 strains in the second experiment. The following were investigated in isolated cultures: the ability to lyse erythrocytes of human and rabbit blood, coagulation of rabbit citrate plasma, the presence of hyaluronidase enzyme, resistance to bacteriocidal strain (bromothymol blue and crystal violet), assimilation of mannitol and pigment formation on lactic saline agar. The pharyngeal microflora was studied by means of rinses as proposed by K.I. Turzhetskiy and E.I. Olen'yeva (1957).

The status of natural immunity of the subjects was evaluated according to the bactericidal function of the skin, determined in relation to *B. Coli*-675 (a smear method, proposed by N.N. Klemparskaya), and to the fagocyte activity of neutrophils in the blood and /84
the content of lysozymes in the saliva.

The investigation of lysozyme activity of the subjects' saliva was carried out according to the method of).G. Alekseyeva (1965). The maximal dilution (titer) of the fasting saliva was determined, during which lysis of a suspension of a standard *Micrococcus lysodeicticus* strain was observed.

Several times before the experiment, study was performed on the autoflora of the tegumental tissues and of natural immunity indices for the production of stable baseline values.

The results obtained were submitted to statistical analysis by means of calculating the X^2-criterion.

Thus, a complex investigation by means of the enumerated methods facilitated determining the functional changes in various systems of the organism and the operative efficiency of the subjects during the experiment.

A. The Investigation of Intellectual Work Efficiency and of Psychic Functions

The investigations of attention showed that the time required for completion of correction tests by all three subjects during experiments with a 24-hour cycle of life activity increased in comparison with baseline data.

Thus, before the experiment, it took subject I. 4 minutes 40 seconds to complete the correction test. While in the hermetically sealed chamber, this time increased to 11 minutes 31 seconds, i.e., 2½ times in comparison to the original data. The time for the completion of the correction test of subject S. increased, but insignificantly. While before the experiment his time equaled 5 minutes 25 seconds, during the experiment the test was completed in 6 minutes 35 seconds.

With the third subject, subject M., the time for the completion of the test also increased (4 minutes 37 seconds before the experiment and 6 minutes in the experimental period).

The number of mistakes in the completion of the correction tests increased to 2½ times the original only for subject M. (before the experiment there were 5 mistakes and during the experiment the /85
number of mistakes was 12). There was no increase in mistakes in the correction tests noted for subjects I. and subject S. Thus the process of concentration in the first experiment was changed for all subjects.*

More decisive changes in the concentration of attention were noticed in all of the subjects with an 18-hour regimen of life activity. In this case, it turned out that during the daytime, when sleep took place during the normal or accustomed nighttime, concentration of attention changed less; and on the other hand, during periods when sleep took place during daytime these indices were markedly worse. Thus, for subject M., on the 5th day of his stay in the chamber the number of mistakes in completion of the correction tests increased to 18. On the 11th day, it was 16, and on the fourteenth day the number of mistakes increased to 20. In comparison with baseline data (6 mistakes) concentration of attention had markedly worsened (see Fig. 3). As far as subject I. was /86
concerned, the number of mistakes in completing the correction test also increased. Before the experiment he only made one mistake; on the 5th day, 6 mistakes; on the 8th, 4 mistakes; on the 11th, 4 mistakes; on the 14th day, 8 mistakes.

In the memory study, the amount of material recalled by subject S. in the first experiment diminished in comparison with data (see Fig. 4). In the second experiment with an 18-hour cycle an

*Ed. note: sic!

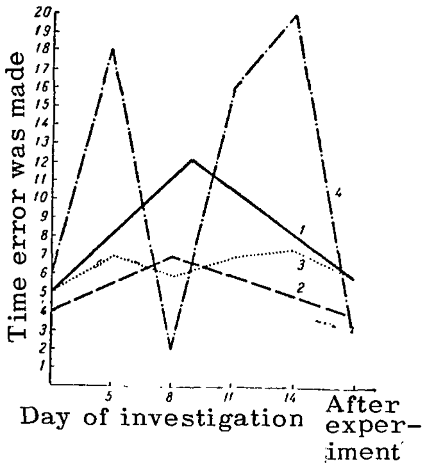

Fig. 3. Change in the Concentration of Attention in First and Second Experiments of Subject M. (1) Errors in 1st Experiment; (2) Time of Completion of the 1st Experiment; (3) Errors in 2nd Experiment; (4) Time of Completion of Second Experiment.

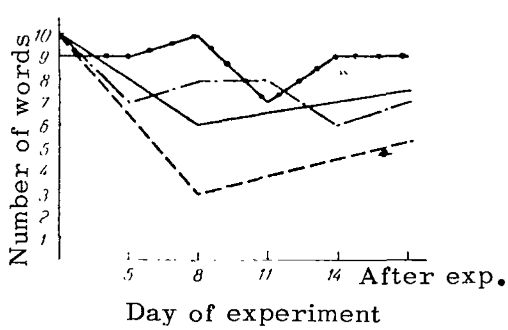

Fig. 4. Change in Memory of Subject S. in First and Second Experiments.

irregularity in remembered material in the daytime was observed.

As far as subject I. was concerned, during the first and second experiments the indicator of quantity of remembered material remained practically unchanged. But the time necessary for remembering the given word increased (in comparison with the baseline data). Changes were noticed also in the investigation of intellectual work efficiency. Both in the first and the second experiments, all three subjects showed an increase in latent time of response on the average of two times the original (association tests).

Productivity of intellectual activity in the first experiment toward the end of the subject's stay in the hermetically sealed chamber diminished insignificantly for all three subjects.

Analysis of the productivity of intellectual activity in the second experiment during watches and the general accumulated data for each day showed a change for the worse, especially with subject S. His productivity of intellectual activity dropped almost by a factor of two during second watch periods.

The intellectual productivity of subject M. fluctuated sharply both by the day and during watches. The intellectual productivity of subject I., during both the first and second experiments, remained irregular without any noticeable lowering at the end of his stay in the hermetically sealed chamber.

From the above-given material it is apparent that far greater changes in psychic function and in intellectual work efficiency on the whole are observed in the second experiment, during which the subjects' regimen of life activity was markedly altered, both in duration and scheduling of hours of work and rest. /87

B. Body Temperature

Twice daily measurements of axillary temperature showed that, in all instances, it remained within the limits of normal values. In this regard it appeared advisable to carry out statistical analysis of the obtained data in order to be able to develop a new diurnal rhythm corresponding to the changed regimen of life, especially for subjects M. and S., whose sleep time, during the first experiment, took place during the day.

With subject I., for whom the time of sleep was normal, there were no deviations from the normal dynamics of body temperature (diurnal rhythm), as was expected. For subject M., the difference between "morning" (P.M.) and "evening" (8 A.M.) temperature appeared to be insignificant (the average values for the period of experiment were 36.3° and 36.6°, respectively). For subject S., the difference between morning (midnight) and evening (4 P.M.) temperature also was not remarkable. In the two latter cases, attention was called to the lack of differences in the values of body temperature upon rising and upon departure for sleep. Thus, by all appearances, a development of a new physiological rhythm of temperature regulation for these subjects did not take place.

In the second experiment, when astronomical times of 0000 hours, 0600 hours, 1200 hours and 1800 hours were alternately, for each subject, first morning and then evening, the values of axillary temperature also did not deviate beyond the limits of the physiological norm, and in addition no indications of a development of a new rhythm of temperature regulation were noted.

C. Body Weight, Daily Energy Expenditure and Fluid Balance

For all subjects in both experiments against a background of a common tendency for a certain amount of weight reduction, fluctuations in the body weight of about 0.5 kg were observed. Energy expenditure for two of the subjects (subject I. and subject S.) only slightly exceeded the caloric intake, 2760 calories on the average (Table 3), and, as a consequence, their weight loss was also insignificant.

Energy expenditures for the separate periods and for whole days in the first experiment (presented in Table 3) were calculated on the basis of data on gas exchange during various types of activity and time study of work operations.

A study of fluid balance was carried out in the experiments (Table 4).

TABLE 3. ENERGY EXPENDITURE OF SUBJECTS IN SEALED CHAMBER

Subject	Energy Losses During Free Time		Energy Losses During the Watch Periods	Energy Losses During the Sleep Period (Corresponding to the Literary Data, Equal to 70 cal/hr. per kg of Body Weight)	Daily Expenditures
	Energy Expenditure of Physical Exercises	Energy Losses During Remaining Free Time			
I.	848.2	995.0	714.0	599.2	3156.4
M.	656.5	775.6	672.0	555.2	2659.3
S.	607.7	963.6	768.0	664.4	3005.7

As is shown by Table 4, elimination of moisture into the chamber during the second experiment, despite the lower temperature of the air, was more intensive in comparison with the first experiment (89.3 and 68.8 ml/hr.).

TABLE 4. MEAN VALUE OF FLUID EQUILIBRIUM FROM CALCULATIONS FOR ONE SUBJECT IN ml IN BOTH EXPERIMENTS (FOR SEVERAL EXPERIMENTAL DAYS) /89

First Experiment with 24-Hour Cycle		Second Experiment with 18-Hour Cycle	
Water Intake	Water Elimination	Water Intake	Water Elimination
(1) Water Contained in the Ration, 836 (2) Water Received by Drinking, 1566	(1) Volume of Diuresis, 1004 (2) Moisture Collected in Chamber, 1636	(1) Water Contained in the Ration, 627 (2) Water Received by Drinking in the Chamber, 1499	(1) Volume of Diuresis, 827 (2) Moisture Collected in Chamber, 1607
Total 2,402	2,640	2,126	2,434

D. Muscular Work Capability

The work capability of a subject--the basic index of the state of neuromuscular activity--suffered a number of changes, one after another, while in the hermetically sealed chamber; changes dependent upon the difficulty of the experiment being carried out and the degree of training of the participants. A change in the work capability of a person who remains for a long time in a hermetically sealed chamber has its own regular laws: thus, on the first day, as a rule, a marked diminution of work carried out through the point of exhaustion is observed, which can be connected through the reaction of the organism to the new conditions of its surroundings. With the development of adaptive mechanisms, the work capability increased somewhat; however, it did not reach the original level. At the end of the period of stay in the hermetically sealed chamber, a constant diminution of the work capability occurred which was not dependent upon the duration of the experiment, which in all probability was connected with an adjustment of the organism to a definite time limit on the experiment. During this period the subjects subjectively manifested weakness and elevated fatigability.

We also observed similar tendencies in work capability changes in the data of the tests. There was a clearly expressed dependency of the amount of work capability in the subjects not only on the conditions of external environment in the sealed chamber, but also on the regimen of work and rest (see Table 5). Thus the quantity of the work completed to exhaustion, in the experiment with the 18-hour daily regimen, diminished from the 34.68 kilogram-meters of the original level to 19.58 kilogram-meters; that is, by 15.1 kilogram-meters, and during the experiment of the 24-hour regimen, /90
the lowering of operative efficiency consisted of only 3.2 kilogram-meters.

TABLE 5. AMOUNT OF CHANGE IN WORK CAPABILITY FROM THE ORIGINAL IN PERCENT

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
First Experiment	100	82.7	85.4	91.3	76.3	114
Second Experiment	100	61.0	71.1	65.5	56.0	95.0

It must be noted that after the end of the second experiment, restoration of operative efficiency was not observed even on the 7th day after the subjects left the chamber. An evaluation of the functional conditions of the neuromuscular activity was also carried out according to the effectiveness of the restoration of work capability, an indication of which was the percentage ratio of the ratio of the amount of work of the second stage to the first stage, which was completed after 2 minutes of rest. This index, as indicated by the preceding experiments, responds sufficiently sharply to the change in environmental conditions. Thus an 18-hour life regimen, which is unusual for a person, in the second experiment led to a gradual growth of fatigue to diminishing effectiveness of the restoration of work efficiency* (Table 6).

TABLE 6. EFFECTIVENESS OF RESTORATION OF WORK EFFICIENCY IN PERCENT

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
First Experiment	64.7	116.3	97.1	70.9	69.0	91.5
Second Experiment	60.2	58.0	62.5	61.0	36.4	34.2

The high values for indices of restoration of work which were noted in the first experiment evidence the sufficiency of a 2-minute rest, especially during the first days of residence in the sealed chamber.

An analysis of ergographic curves indicated that the length of the ergogram of this unique index of the functional status of the motor center of the cerebral cortex was significantly shortened in the period of the subjects stay in the hermetically sealed chamber. In addition, a more distinct shortening took place during the 18-hour regimen of work and rest. Moreover a uniform trend in changes in the length of the ergogram was observed with the changes in the amount of work capability (Table 7). Changes in the amplitude of /91

TABLE 7. LENGTH OF ERGOGRAPHIC CURVE IN PERCENT

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
First Experiment	100	83	85	91	76	91
Second Experiment	100	61	71	66	56	96

ergogram were insignificant and did not exceed ±0.56 m.

The data of the dynamometric investigations permit the observation that the muscular strength of the hands diminished only at

*Ed. note: Actually, the efficacy of rest.

the end of the extended stay in the chamber. A loading of the conditions of work and rest in the second experiment led to a more marked lowering of muscular strength, which by the third day in the hermetically sealed chamber had already diminished by 16% (Table 8).

TABLE 8. MUSCULAR STRENGTH OF THE RIGHT HAND IN KILOGRAMS

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
First Experiment	54	58	54	52	54	54
Second Experiment	57	48	50	42	52	54

In both experiments, changes in the amount of strength at the bicycle ergometer were insignificant and did not exceed 3-6% of the original level. It is characteristic that in an earlier experiment carried out in the hermetically sealed chamber, strength at the bicycle ergometer diminished to a greater degree than the muscular strength of the hands, which evidently is connected with the predominance of supplementary statistical stresses in a room of limited volume, stresses which could only influence the amount of standing strength*.

The functional condition of the motor center of the cerebral cortex was also evaluated on the basis of an investigation of precision of movement. In the second experiment, for this evaluation supplementary data for determining the muscular tone were used. /92

An analysis of the obtained results allowed one to note a certain increase in the number of mistakes per unit rate in the second experiment (Table 9).

TABLE 9. CHANGES IN THE INDEX OF PRECISION OF MOTION (CONDITION UNITS)

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
First Experiment	4.7	6.4	4.7	3.5	5.6	4.9
Second Experiment	4.7	4.2	5.2	5.0	5.9	6.3

The functional status of the cerebral cortex motor center was also evaluated on the basis of movement accuracy studies. Muscle tone studies were also employed in the 2nd experiment for such evaluation.

*Ed. Note: The original is confusing here. It could read, "...associated with the predominance in the room of a limited quantity of extra statistical stresses..."

Analysis of the findings revealed some increase in the number of mistakes per unit rate in the second experiment (Table 9).

Determination of the tone of the femoral muscles was made before and after work on a bicycle ergometer. The results of the investigation were expressed absolute units of the scale of a myotonometer. The obtained data (Table 10) attest to diminished muscular tone during the period in the chamber, which reflects the lowering of strength both of the excitory and the inhibitory processes of the central nervous system. Average physical stress--work on a bicycle ergometer--as a rule, led to further lowering of the tone of the femoral muscle.

TABLE 10. THE INFLUENCE OF PHYSICAL STRESS ON THE MUSCULAR TONE OF THE FEMORAL MUSCLES (ARBITRARY UNITS)

	Before Exp.	Day of Exp.				After Exp.
		3	5	9	13	
Before Work on Bicycle Ergometer	23.2	17.6	9.2	7.2	6.8	11.6
After Work on Bicycle Ergometer	14.4	12.8	8.0	8.0	4.8	7.4

As follows from Table 10, the negative influence of the physical stress on the muscular tone lessens somewhat with an extended experiment, which, however, is relative and depends basically on a /93 more pronounced lowering of the muscular tone before work on a bicycle ergometer.

Thus the neuromuscular activity of a man under conditions of extended stay in a hermetically sealed chamber undergoes definite changes leading to a decrease in work capability and to the growth of fatigue in the subjects. In addition, the depth of the changes depend upon the stress of the life conditions, including a correctly organized regimen of work and rest.

E. Investigation of Conditions of the Cardiovascular System

While a man is in a hermetically sealed place of limited volume, definite changes in functional condition of the cardiovascular system are observed.

In connection with this, it is of great interest to study the cardiovascular system of a subject while he is engaged in active work under various conditions of life regimens.

Investigation of the pulse rate of the subjects in the first experiment showed a marked lowering.

Changes in arterial pressure in the given experiment with various subjects was uneven. Thus with subject I., whose life activity progressed in a regimen of an unchanged daily periodicity, there was a notable lowering of a maximum and minimum arterial pressure during the entire experiment.

With subjects S. and M. in the presence of a general tendency toward the lowering of arterial pressure on separate days of the experiment, there was an elevation of the maximum and minimum pressure in which the level of maximum pressure in separate instances exceeded the baseline value.

Pulse pressure in the experiment with 24-hour daily cycle changed insignificantly, and did not exceed the bounds of 35-55 mm Hg, which evidently can indicate a sufficiently good functional condition of the circulatory apparatus.

In the second experiment there was also a lowering of the pulse rate with all three subjects. A dependency of the frequency of coronary contractions on the time of waking was more pronounced in subjects S. and M.: upon waking at 0600 hours and 2400 hours the pulse rate lowered in comparison with the baseline data, to a greater degree than upon waking at 1200 hours and 1800 hours (Table 11). /94

Table 11 presents the data of pulse rate in experiments with 8-hour daily cycle depending upon the time of awakening of the subject.

Maximal pressure in the second experiment dropped in all subjects. In addition, a dependency of the degree of lowering of maximal pressure on the time of waking was noticed.

As is shown in Table 12, maximum pressure lowered more significantly when the subjects awoke at 0600 hours. With waking at 1200, 1800 and 2400 hours, a high value of maximum pressure is observed.

Changes in the minimal pressure did not have pronounced character. In addition, it is possible to note a somewhat higher level in subject S. (70-84 mm Hg).

In order to evaluate the tonus of the vascular system, methods of defining the speed of propagation of pulse waves (SPPW) were used.

SPPW in the left hear-carotid artery section in both experiments remained practically unchanged. The time of passage of the pulse wave was found to be within the limits of 0.03 to 0.04 seconds.

SPPw over the arc from the left heart to a toe of the right foot changed during the course of the second experiment from 5.3 to 6.4 m/sec (beginning of the experiment) to 5.6 to 6.9 m/sec toward the end of the experiment.

SPPW from the left heart to a finger of the right hand (a determination was made only in the experiment with 18-hour daily cycle) during a stay of the subject in the hermetically sealed chamber was from 4.8 to 5.8 m/sec at the end of the experiment.

Thus, as is seen by the above-given data, the tone of the main vessels in various portions of the vascular system increased somewhat.

Electrocardiogram analysis in both experiments showed a certain increase in the *PQ* interval of subjects I. and S.

TABLE 11. PULSE RATE AFTER SLEEPING IN CYCLES /95

Time of Day (hours)	I.						S.						M.					
	До	1	2	3	4	5	До	1	2	3	4	5	До	1	2	3	4	5
6	—	60	60	64	60	54	—	52	54	52	48	—	—	48	52	56	54	56
12	84	64	54	60	60	54	66	60	60	60	54	54	72	54	60	62	52	—
18	—	66	54	60	60	52	—	52	56	60	54	54	—	64	66	54	60	60
24	—	60	56	54	60	64	—	52	56	48	54	56	—	66	54	48	54	52

TABLE 12. MAXIMUM PRESSURE AFTER SLEEP IN CYCLES

Time of Day (hours)	I.						S.						M.					
	До	1	2	3	4	5	До	1	2	3	4	5	До	1	2	3	4	5
6	—	96	94	100	100	104	—	104	102	98	102	—	—	92	90	100	100	100
12	115	104	108	104	90	98	114	104	108	110	98	102	114	100	110	110	106	—
18	—	108	110	108	104	98	—	112	94	106	110	108	—	110	110	108	102	106
24	—	100	110	108	114	110	—	104	98	100	104	108	—	100	104	102	100	98

Phase analysis of the cardiograph cycle (polycardiograph) in both experiments showed a statistically reliable increase of the mechanical systole of the left ventricle of the heart due to an increase in the expulsion phase (isoelectric systole). A protodiastolic period and phase of isometric systoles in addition practically did not change. /96

The baseline data for the expulsion phase were within the bounds of 0.23 to 0.27 sec toward the end of the experiment. The duration of the expulsion phase was elevated to between 0.29 and 0.32 sec, and after the end of the experiment it gradually lowered to the original value.

The duration of the mechanical systole of the left ventricle in the experiments also increased (from 0.28-0.3 to 0.32-0.36 sec).

F. Functional Status of External Respiration

Great changes in these functions were not established by means of the above-mentioned investigations. It was made clear that the oxygen demand and consequently, basal metabolism, did not change in comparison with baseline values. It is true that in the second experiment, with subject I. on a 24-hour and subject M. on an 18-hour regimen, in separate periods, an increase was noted in demand (up to +30.7% above the norm), but on the whole, during the period of experiments changes were uncertain.

With unchanged oxygen demand, the coefficient of oxygen use during these days lowered and the ventilation equivalent increased, which could evidence a worsening of ventilation effectiveness and a lowering of diffusion ability of the lungs. On the basis of given data, to be sure, from a small number of observations (27 measurements) it is also possible to conclude that the astronomical time as such does not influence the rate of basal metabolism, if all other conditions are fulfilled.

G. Investigation of Peripheral Blood

Changes in peripheral blood did not exceed the limits of the generally accepted physiological norms. The illustrations shown here give individual data pertaining to each subject received throughout the period of observation and the mean values reflecting /97 a general tendency for changes of some hematological indices.

Changes on the part of red blood cells were characterized by an increase in the quantity of hemoglobin of two subjects from 16-17% (normal level, 14-15%). At the same time, in two of the subjects during and after the end of the first experiment, a certain decrease in the quantity of erythrocytes was observed. The indicated changes give evidence of the presence of definite hyperchromia and an increase in the amount of reticulocytes of two subjects in the first experiment, and a significant increase in their quantity in all subjects in the second experiment (Fig. 5). Data obtained during the study of the function of external respiration indicate an insufficiency in the oxygen supply of the organism.

Definite changes were also observed on the part of the white blood cells. The quantity of leucocytes increased somewhat during the first experiment, and was especially marked on the second to eighth day of the second experiment (see Fig. 6).

Increase in the quantity of leucocytes took place basically because of the increase in the number of neutrophils, especially lymphocytes. The latter evidently can be explained by development of fatigue in the subjects, which is supported by the data and other investigations.

Osmotic resistance of erythrocytes in the blood of the subjects in the second experiment underwent the following changes.

At the beginning of the experiment, the maximal value was recorded in subject M.: in a 48 mg% solution of sodium chloride, 53% of his erythrocytes were whole; in a 44 mg% solution of sodium chloride, 25% of the erythrocytes were whole. It was even lower for subject S.: in a 48 mg% solution, only 26% of his erythrocytes were whole (Table 13). The difference in indices in the respective subjects is statistically verifiable. /98

Fig. 5. Change in the Quantity of Reticulocytes in the Subjects' Blood. I - 1st Experimental Period; II - Second Experimental Period; R - Recovery

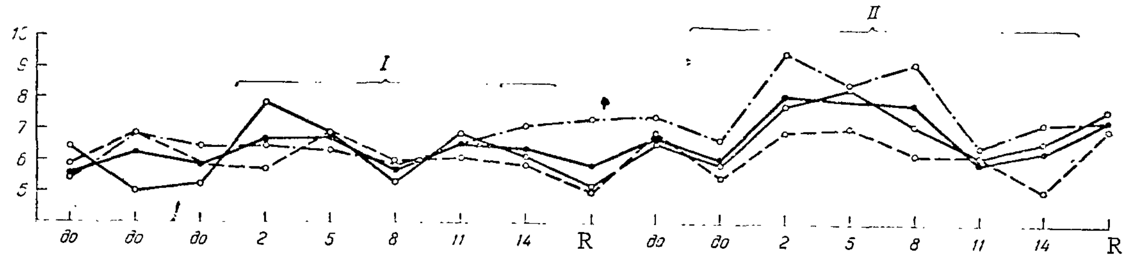

Fig. 6. Change in the Quantity of Leukocytes in the Subjects' Blood. Designation are the Same as in Figure 5.

TABLE 13. A CHANGE IN THE OSMOTIC RESISTANCE OF ERYTHROCYTES OF PERIPHERAL BLOOD IN THE EXPERIMENT WITH AN 18-HOUR DAILY CYCLE /99

Subject	Period of Observation	Number of Observations	% of Whole Erythrocytes in 48 mg % Solution† of NaCl
M	Before Experiment....	7	53±2.4
	8th Day..............	7	82±2.6
	11-14th Day..........	12	61±2.6
	After Experiment.....	5	41±1.3
I	Before Experiment....	6	41±5.0
	8th Day..............	6	57±6.5
	11-14th Day..........	11	35±3.4
	After Experiment.....	5	16±4.0
S	Before Experiment....	5	26±5.6
	8th Day..............	5	55±6.2
	11th Day.............	5	14±4.5
	14th Day.............	5	23±4.3
	After Experiment.....	5	13±4.0

† Concentration of 48 mg% in a given case proved to be a very characteristic - "broken" point in the hemolysis curve.

On the 8th day of the experiment, a distinct rise in the resistance of erythrocytes in comparison with the original data was noted for all three subjects. Thus, for subject M. before experiments in a 48 mg% solution of sodium chloride, 53% of the erythrocytes were whole, and on the 8th day, 82%. For subject I. these values were, correspondingly, 41 and 57%; for subject S. they were 26 and 55%. Thereafter the stability of erythrocytes begins to fall, and on the 11th day of the experiment in the 48 mg% solution of sodium chloride for subject M., 61% of erthrocytes were whole; for subject I., 35%; and an especially sharp drop in this index was noted on this day for subject S. (14%).

Subsequently for two of the subjects, M and I, the values characterizing osmotic resistance of erythrocytes remained at the level reached on the 11th day; the difference between the 11th and 14th

day was practically nonexistent, and only for subject S. was there a sharp drop in the resistance of erythrocytes from the 11th day to the 14th day. The difference in the values between these days is statistically reliable. Observation of the subjects after their exit from the chamber showed a lowering in the stability of erythrocytes to the norm (for subject S.) or below the norm (for subjects I. and M.). Thus with a 15 day experiment consisting of 20 18-hour cycles, osmotic resistance of erythrocytes for the subjects changed significantly several times in a regular fashion: it rose toward /100
the middle of the experiment and lowered toward the 11th day, remaining at this level up to the end of the experiment, and again lowered after the exit from the chamber. The only disturbance in this regularity was a certain elevation in the index under consideration for subject S. on the 14th day (see Table 13).

H. Urinalysis

Results of the investigation of daily diuresis show that on adduction of a daily volume of deaminized protein after 24 hours, in the second experiment a mean volume was received equal to 114.2 grams per day, which was an increase of almost 20 grams above the quantity collected in the first experiment. Consequently deaminization of protein and the necessity for it was greater in the second experiment, which can evidence the fact of the more difficult conditions of this experiment.

I. Microflora of the Tegumental Tissues and the Condition of Several Indices of Natural Immunity

A man's residence in a hermetically sealed place of limited volume is usually accompanied by an elevation in the level of microcontamination of the skin and of the mucous membrane of the oral and and pharyngeal cavities.

In the first experiment, the level of microcontamination of the skin for the various subjects for the whole duration was unequal. However the quantity of microorganisms living on the teguments significantly exceeded the average level established for a healthy person (Table 14).

An especially marked increase in the usual number of microorganisms on the skin was noted for subject I. It is necessary to note that both before the experiment and during it, the quantity of microbes on the portions of the skin covered by clothing and the portions not covered by clothing were the same, and the change of level in microbe spore formation was monotypic.

Data on the composition and quantity of microoganisms on the various portions of the skin agree with our data received in the series of preceding experiments in which an identity of the changes was indicated in the quantity of bacteria on the skin of the inner surface of the right forearm, and of the left half of the stomach

TABLE 14. USUAL NUMBER OF MICROORGANISMS ON THE SKIN OF THE FOREARM AND SHOULDER BLADE OF THE SUBJECTS IN THE FIRST EXPERIMENT /101

Subject	Place Investigated	Number of Colonies Before Experiment			Day of Experiment			Number of Colonies After Experiment
					5th	8th	14th	
I	Forearm	70	90	40	780	370	1,300	40
	Shoulder blade	70	150	140	920	460	600	190
M	Forearm	180	70	340	480	80	350	220
	Shoulder blade	120	110	50	230	-	50	260
S	Forearm	160	220	160	110	160	36	80
	Shoulder blade	70	90	150	170	100	30	40

during exposure of the subjects in the hermetically sealed place. The content of hemolytic forms of bacteria during the experiment changed insignificantly.

A certain increase in the quantity of staphylococcus, reflecting high hyaluronidase and coagulates, was observed on the 14th day of the experiment and at the end of the experiment.

On the 8th day of experiment, on the skin of subjects a rise in the staphylococcus content was noticed which was resistant to biomycin and levomycetins. This is especially pronounced with subjects M. and I.

Microbe spore formation in the oral and pharyngeal cavities of subjects markedly increased. It was especially pronounced on the 5th day of the experiment, when the total number of microbes increased, in comparison with the baseline level, 400-500 times. The basic quantity of microorganisms manifested during this period was represented by nonhemolytic streptococci.

The investigated natural immunity indices were within the bounds of the baseline level.

In the second experiment, clothing was used which had been made from bactericidal fabric.

In connection with this in the second experiment, several changes were noticed in the makeup of microflora on the skin of the /102 subject related basically to the action of the bactericidal agent of the clothing on the microorganism.

The total number of microbes on portions of the integument covered by clothing and not covered by clothing increased. However, this increase was less pronounced than in the first experiment. By the end of the experiment, a lowering was observed in the amount of staphylococci bearing signs of pathogenesis and resistance to biomycin and levomicetin.

Microbe contamination of the oral and pharyngeal cavity of the subjects in the second experiment, just as in the first, was markedly increased.

As is well known, phagocytosis is one of the more characteristic indices of nonspecific immunity, inseparably connected with general and immunological reactivity of the organism (I.I. Nechnikov, 1950; V.M. Berman and E.M. Slavskaya, 1959, et al.).

Lately, the phagocytic reaction has been broadly used for evaluation of the influence of various factors of the external environment on the human organism (V.K. Navrotskiy, 1957; A.I. Pakhmoychev, 1960; A.F. Stoyanovskiy and T.V. Rasskov, 1961, et al.). The investigation of phagocytic activity of neutrophils of the blood showed that with an increase in /103
the length of the subjects' stay in the chamber, a lowering of phagocytic reaction (Fig. 7) took place.

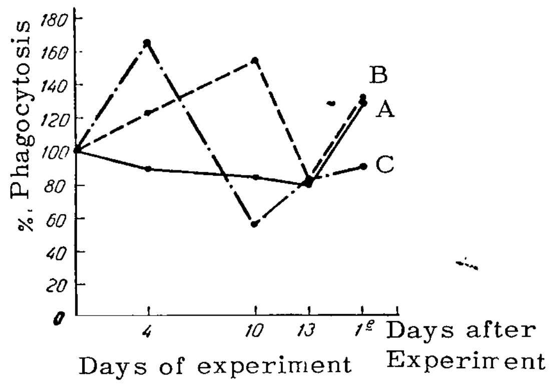

Fig. 7. Phagocytic Activity of Neutrophils in the Blood of the Subjects. A - Subject I.; B - Subject M.; C- Subject S.

As seen in Figure 7, on the 13th day of the experiment the percent of phagocytosis dropped for all subjects by 15-18.8% in comparison with the baseline level. Moreover, with two of the subjects (I. and S.), simultaneous with lowering of the phagocytic activity of neutrophils, a diminishing intensity of phagocytosis (phagocytic index) was observed (Fig. 8). Thus, for example, before the experiment the phagocytic index of the subject equals 1.27-1.47 and on the 10th day and 13th day of experiments it was, respectively, 0.6 and 0.4-0.7; i.e., it dropped by 2-3.6 times in comparison with the baseline level.

The lysozyme activity in the saliva of the subjects dropped steadily for the duration of the experiment (Fig. 9). At the end of the experiment the titer of lysozme from all subjects dropped approximately 10-20 times. A day after leaving the chamber, a rise in lysozyme activity was noticed.

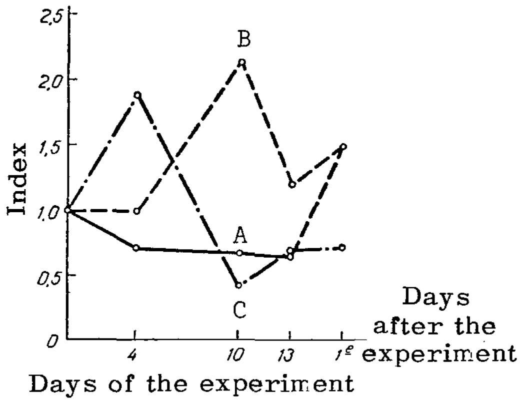

Fig. 8. Intensity of Phagocytic Reaction.
A-Subject I.; B-Subject M.; C-Subject S.

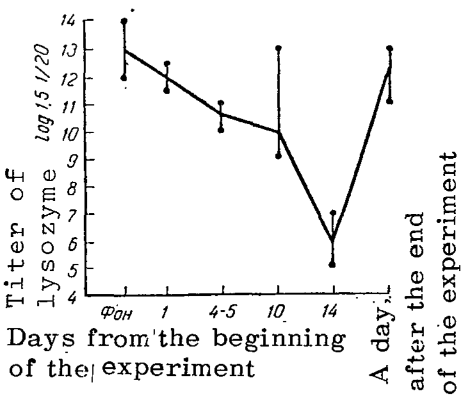

Fig. 9. Dynamic Lysozyme Activity. Vertical Lines Indicate Individual Indices of Lysozyme in the Saliva.

Discussion of the Results of the Investigations

A person's extended /104 stay in a hermetically sealed chamber of limited volume takes place under living conditions which are greatly different from those to which he is accustomed. The basic distinguishing property consists in that when a man is placed in a sealed chamber, the air environment is polluted by means of chemical substances and microorganisms, in which the processes of human life activity show definite dependency on these environmental changes. A man under these conditions becomes a basic causative agent of these changes in the environment.

A characteristic property of habitation in a hermetically sealed place is likewise that a man undergoes the simultaneous action of a complex of unfavorable factors. In addition, it must be noted that the simultaneous action of many factors, despite low intensity, can elicit definite changes in the functional status of a human organism. Thus, according to data of many investigators (R.I. Sklyanskaya, 1944, et al.), high air temperature strengthens the permeability and absorbability of the carbon monoxide in the air and promotes its effect. The fact is also well known that the accumulative action of several toxic substances elicits, in a number of circumstances, a greater effect than that which would be defined by the simple sum of the effects of each of them individually.

Constant exposure to such an environment of habitation cannot be without serious consequence for the human organism. As a consequence of this, it is possible for a unique accumulation of physical effects to appear, as was observed in our investigations, when the worsening of the functional condition of many systems became dependent upon the length of the experiment. The established regular loss took place during the execution of the two experiments described above, in which the influence of various regimens of work and rest on the human organism was studied. In addition, the observed changes in the condition of the organic systems and functions of the subjects were characteristic for any human occupation in a hermetically sealed chamber, and primarily caused general asthenia to develop.

A basic index of the status of the human organism, under the given conditions of habitation, is an evaluation of the functional condition of the central nervous system, permitting one to characterize the complex processes of adaptation to unusual conditions of existence and to trace the restructuring of activity of the cerebral cortex to a new functional level. /105

As was established in numerous experiments, the changes on the part of the higher nervous activity during a person's stay in hermetically sealed place of limited volume, characterized by a basic weakening both of the excitatory as well as of the inhibitory process where they are predominant, include the worsening of internal inhibition. A change in indices of psychic activity, such as the time for completion of correction tests, latent response time in association experiments, evidently also can attest to worsening mobility of nervous processes.

Results of investigations of neuromuscular activity indicated that a stay under the conditions of a hermetically sealed place elicits characteristic deviations of the neuromuscular apparatus: worsening of the indices of capacity for work, lowering of muscular strength, worsening and lessening in muscular tone and worsening of precision of movement.

The changes which have been noted, especially the lowering in the capacity for work, evidence a diminishing of the reserve capacity of the organism. The causes for the observed changes are basically changes in the central link of the motor analysor of the cerebral cortex.

The functional status of the cardiovascular system of the subjects in the experiments also changes. Noted in both experiments was a lowering of the maximum arterial pressure and a diminishing of pulse rate, an increase in the *PQ* interval and a rise in the pulse rate propagation speed. The indicated changes in hemodynamics appear to be typical for periods of human occupation of hermetically sealed places of limited volume.

During the time of occupancy, subjects in hermetically sealed chambers showed an increase in the microbe spore formation on the skin and mucous membrane. An increase in the usual number of microbes on the integuments was accompanied by a rise in the number of bacteria bearing specific signs of pathogenesis. The quantity of microorganisms capable of lysing erythrocytes from human and rabbit blood increased. These microorganisms could grow on a bouillon medium and they incorporate mannitol while forming hyaluronidase.

The cause leading to collective and qualitative changes in the autoflora can be considered as a lowering of a person's immunobiological reactivity.

Thus, as becomes apparent from the above given data, during the period of a person's stay in a hermetically sealed chamber of limited volume, pathological changes in the condition of his organism are not observed. The simultaneous and uninterrupted action of unfavorable factors combined with their small intensity create conditions for the appearance of a cumulative effect, which occasions the development of a unique reaction of the organism in response to the action of an entire complex of unfavorable factors.

Change in regimen during the second experiment (the introduction of an 18-hour daily cycle) elicited a strengthening of the manifestation of changes in functional conditions of various systems of the organism of the subjects.

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THE INFLUENCE OF A CHANGE IN REGIMEN OF THE DAILY ACTIVITY ON THE HUMAN ORGANISM UNDER CONDITIONS OF ISOLATION

V.I. Myasnikov

ABSTRACT: A number of experiments were conducted in which men were isolated in a soundproof chamber for extended periods of time. The regimens of work and rest which the subjects followed were varied. The results of these investigations, particularly the psychophysical effects on the organism, are presented.

The development of principles and methods for the rational organization of a regimen of daily activity for astronauts is one of the leading concerns in the practice of space medicine. In the opinion of several authors (B.F. Alyakrinskiy, 1966, et al.), the successful solving of this question is impossible without taking into account conditions such as the constructive properties of the cabin of the space ship and of work areas, the characteristics of activity, the number of crew members, etc. However, in our opinion an enumeration of conditions will be incomplete if it does not take into account the characteristics of a person's life activity from the point of view of his daily stereotype in time and of his emotional development, which has been worked out and strengthened in the process. It is known that the human organism has limited reserves at its disposal for the process of restructuring the physiological cycle of waking and sleeping in relationship to both time and the preservation of strength of the conditions of homeostasis, in the broadest sense of the word. It has been shown that, in the first place, restructuring does not take place instantaneously: the time demanded for this is from 1 to 2 weeks (O.P. Shcherbakova, 1949; A. Emme, 1962, et al.). In the second place, it is connected with definite functional disturbances, which are expressed by feelings of hunger, drowsiness, insomnia, etc. (Strughold, 1965). The latter is more pronounced in elderly persons and also depends on the characteristics of the new regimen of work and rest. Hauty (1916), studying the capacity for work of radar station operators, explained that the restructuring of usual regimen in small increments, frequently alternating periods of waking and sleeping during the course of the day, brought about a lowering of the work capacity and the development of sleepiness during periods of "service" wakefulness. The author does not give any physiological basis for the phenomena noted, except for references to the fact of change in the usual life pattern. /107

Regarding the insufficient progress in solving the problem of work and rest relative to the task of space flight, experiments were carried out for studying the influence of various regimens of daily activity on the functional status of the organism under /108 the conditions of isolation.

We carried out a number of investigations lasting 10-15 days in a specially equipped chamber (soundproof chamber) with the participation of healthy men, ages 23-25 years. The chamber was equipped with special apparatus and instruments comprising a system for the introduction of stimuli and for the collection of information from the chamber, information which characterized the functional condition of the organism and the work of the life support systems.

The basic circumstances of the investigation--standard isolation of the subject--provided: for isolation, a lack of two-way speech communication, and practically complete isolation from external sources of light, sound effects and other stimuli. A one-way communication connection from the subject to the experimentor was limited according to a programmed time of transmission.

The activity of the subjects during the period of investigation was strictly regimented by a daily schedule which included: performing experimental psychological tests and assignments, recording and evaluating instrument readings, using work apparatus, relaying reports, breaks for recording physiological functions (putting on electrodes, measurements of interelectrode resistance, etc.), taking care of personal hygiene needs, preparing food, etc.

Various regimens of daily activity were used in the experiment (Fig. 10): normal (work by day, sleep by night); altered or shifted (work by night, sleep by day); and broken up or fractional, with numerous alternations of periods of waking and sleeping during the course of the day.

The duration of sleep in all experiments was 9 hours.

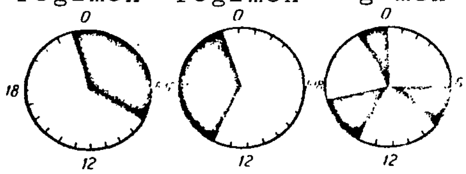
Evaluation of the functional status of the subject was made using a combination of the following:

(1) data from the observation of behavior and emotional reaction;
(2) the dynamics of bioelectric activity in the cerebral cortex;
(3) the results of the determination of speed of motor reaction response;
(4) on the basis of factual completion of experimental psychological tasks (tests on soundproofing, worked out by F.D. Gorbov and L.D. Chaynova, 1959).

Evaluation of individual behavioral characteristics is made on the basis of visual data and observation by means of television and filming the subjects, in combination with the results of all other methods of investigation. This permitted not only a more complete characterization of such main points in the daily rhythm as falling asleep and waking, but also judging the adequacy of behavior in periods of extended experiments on isolation.

Biopotentials of the brain were registered from symmetrical portions of the brain with bipolar leads (forehead-temple). Four electrodes and silver wires 7-8 mm in diameter, wrapped in gauze and moistened in a physiological solution with addition of a special paste were used. A record of the biopotentials was made on an 8-channel recording electroencephalograph, "Al'var". At time of recording, the subject sat in a chair in darkness with his eyes closed. A light stimulus (flashing light at a frequency of 9-11 pulses per second and a duration of 5 seconds each) was given with a photostimulator, situated 60-80 cm from the eyes of the subject. During the presentation of the light stimulus the subject opened his eyes, and on completion he closed them.

Normal regimen   Shifted regimen   Broken up regimen



Waking; Sleeping

Fig. 10. Scheme of Regimens of Daily Activity of Subjects in Experiments With Isolation.

The basis of the investigation of the speed of motor reaction /110
response was the method of definition of the latent period of reaction to the simultaneous registration of an electromyogram (EMG) from the flexor digitorum profundus of the right hand; the demanta galvanic reflex (dgr) according to the method of Tarkhankova--the difference in potentials between the palmar and dorsal surfaces of the left hand; electroencephalogram (EEG) from symmetrical portions of the head with bipolar (forehead-temple) leads. As a means of stimulus, a short series of light pulses was used. Investigations were carried out repeatedly at intervals of 20-30 seconds. Closing the hand was motor response reaction.

In order to study resistance to distraction, work with number selection according to given program was performed. For this they used square tables with numbers colored black (from 1 - 25) and red (from 1 - 24), distributed in random combinations, thus excluding the possibility of memorization. (Calculation operation, at the basis of the program, consisted in combining a natural series of numbers in ascending and descending order.) Responses were recorded uninterruptedly on a magnetic tape. Data on the factual responses of the subjects were expressed in graphs, which appeared as two columns of numbers (in the order of response from top to bottom) in order to visualize the investigated data in the upper and lower part at a distance proportional to the numerical difference between the numbers of the corresponding pair, in such a way that a number of the black and red rows with the least difference (12-13) immediately adjoined one another. The time lapse between responses was placed on a fixed scale opposite the corresponding numbers.

Investigation showed that "a distortion" of the usual life order (a transition from one rhythm of sleep to another) against the background of extended isolation had a definite influence on the organism, leading in some circumstances to the appearance of fatigue.

As has been explained, there was less fatigue during the normal daily regimen of activity than with a broken up or shifted regimen. In addition, the impression of insufficient rest was created for the time which had been devoted to sleep, which led to gradual growth of fatigue. The latter was characterized by the onset, beginning on the 5-7th day of the experiment, of a sensation of physical fatigue. /111

The subjects demonstrated a need for conversation and for increasing communications with the experimentor, which is shown by structuring the reports in question form, by requests for the correct time, and by the inclusion in reports of "extraneous" words and expressions which had not been specified in the instructions and which contained a direct relationship to the experimentor. At this time, there were periods lasting to 20-30 minutes when the subjects sat idle with an absent look on their faces. While reading books, it could be seen that they quickly glanced over the text, mechanically turning the pages; they continued reading for a short time, sometimes not even trying to find the place in the book where they had stopped earlier.

Observations of the personal conduct of subjects in the experiment with the broken up and especially the shifted regimen showed the development of a sleepy condition during the periods of wakefulness at the time of breaks, when they were free from the demand to complete physiological and experimentally psychological tasks.

The development of sleepiness in periods not demanding active attention arose, evidently the consequence of the "falling off of masses of stimuli, which usually enter the cerebral hemisphere" (I.N. Sechenov, 1963), and the change in the usual regimen of daily activity led to the development of these conditions.

The development of this sleepy condition in periods of wakefulness influenced the quality of sleep. It became shallow; for a long time the subject could not fall asleep, and if he did fall asleep, then often he lost the ability to wake up independently at the given time.

The feeling of fatigue is accompanied by a lowering in the quality of the completion of the psychological test and by an entire complex of changes on the electroencephalograms. The character of these changes was closely connected with the regimen of daily activity. For example, the bioelectrical activity of the brain of subjects on the usual regimen of activity, 60% of the time, was characterized by a lowering in the amplitude of alpha rhythm on the original EEG curve. In experiments with the shifted rhythm from the 2nd-5th day, on the EEG a lowering of amplitudes of the biopotentials and instances of diffuse slow waves were noted. The alpha rhythm index in experiments with normal regimen of daily activity changed insignificantly, lowering toward the end of the experiment /112 by 2-15% of the original level. In experiments with a shifted regimen, the alpha rhythm index lowered more significantly; by 13-33%

in the first days, by 61-90% on the 5th and 82-99% on the 10th-15th day of the experiment (V.I. Myasnikov, 1964) (Fig. 11). Seventy-five % of the changes in the bioelectrical activity of the brain in subjects on a broken up regimen were analagous to the changes in the biopotential of the brain in subjects on the usual regimen, and only 25% were similar to the dynamics of bioelectrical activity characteristic of a shifted regimen. The index of alpha rhythm toward the end of the experiment lowered by 17-51%.

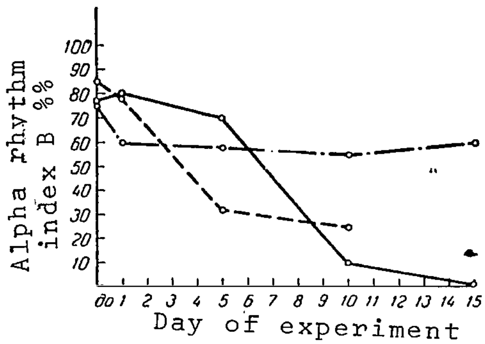


Fig. 11. Changes in the Index of Alpha Rhythm on EEG of Subjects Under Various Regimens of Daily Activity.
.—.— = Normal Regimen, Subj. L.
——— = Shifted Regimen, Subj. S.
---- = Broken Up Regimen, Subj. G.

A study of the residual reactions of the EEG of the subject showed a rise in bursts of alpha rhythm as a result of the rhythmic light stimulus in 71% of the cases. Analysis of the residual reactions from the point of view of duration of flow, showed that the duration of the alpha rhythm exaltation depended upon the regimen of daily activity taken in the experiment. Particularly on the part of the subjects in experiments with a shifted regimen, alpha rhythm exaltation became longer in accordance with the length of stay under the conditions of isolation (Fig. 12), acquiring on the 6th-7th day a depressed nature which could be interrupted only by a subsequent stimulus (V.I. Myasnikov, 1963). /113
While studying problems of the electroencephalography of sleep, P.I. Gulyayev (1955) noted a qualitative difference in the course of residual reactions among people during sleep and differing manifestations of fatigue. Analyzing the data which we received from this point of view, we came to the conclusion that expressivity and duration of the passage of alpha rhythm exaltation in various subjects was unequal and connected with the peculiarities of functional changes. Among subjects, the manifestations of fatigue, exaltation of alpha rhythm was of a depressed nature, just as with people showing pronounced drowsiness. Residual reactions were noted in the form of a burst of exalted alpha rhythm (Fig. 13) of short duration (not more than 10 seconds). Investigations showed also that changes in the bioelectrical activity of the brain, after the exclusion of light stimuli, began with varying speeds: exaltation of the alpha rhythm in subjects with the onset of drowsiness appeared only after repeated presentation of light stimulus (Fig. 14).

A varied expressivity in the length of the passage of residual reactions is connected, evidently, with the characteristics of the functional changes in the central nervous system, which has been dictated by a sleepy condition in some circumstances and by the onset of fatigue in others. Not stopping to analyze the qualitative differences between these conditions, it is necessary to say that the depressed character of exaltation on the background of a diffuse flow of waves and the lowering of biopotential amplitudes, reflecting the complex restructuring of the cortical functions according to the parameters of lability and excitation, was evaluated as a sign characteristic of fatigue. On the other hand, brief flashes of synchronized and exalted alpha rhythms in subjects exhibiting pronounced drowsiness was more characteristic for a diffuse inhibition is a result of a sleepy condition. This same

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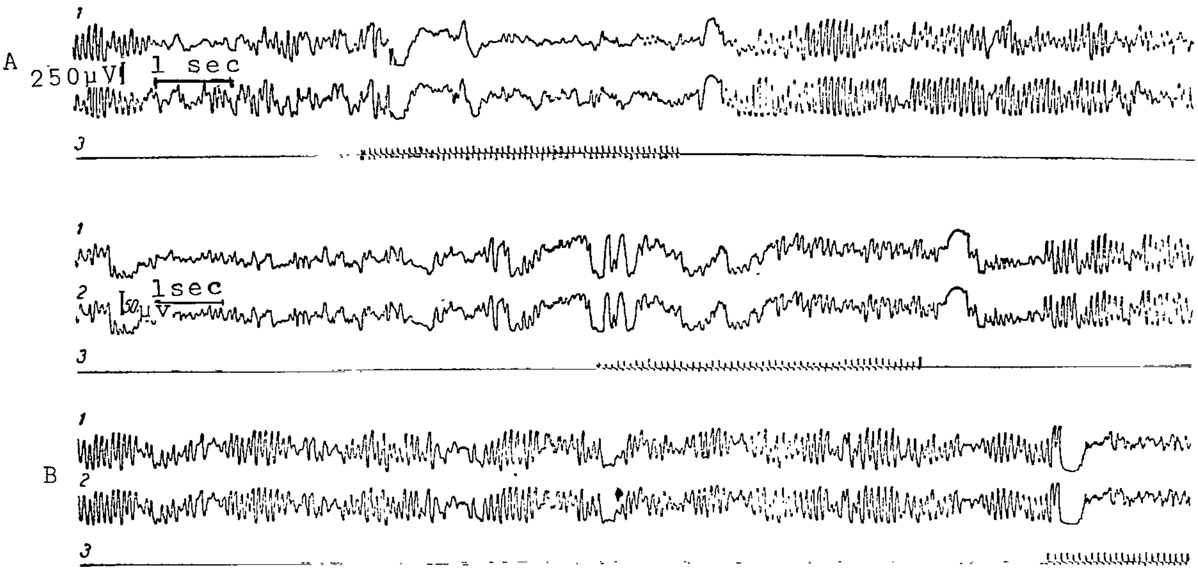

Fig. 12. Dynamics of Prolongation of Residual Reactions on the EEG of Subjects in Isolation With a Shifted Regimen of Daily Activity. (1) EEG Forehead-Temple, Right; (2) EEG Forehead-Temple, Left; (3) Mark of Stimulus; (A) Prolongation of Exaltation of Alpha-Rhythm on 5th Day of Experiment; (B) The Same on 12th Day

condition indicates that among these subjects, the pulse of alpha rhythm exaltation arose often only after repeated presentation of light stimulus, which is the result of stimulus accumulation and indicates a lowering of the functional mobility of cortical neurons.

Investigations of the speed of the motor reaction response (V.I. Myasnikov, 1964) showed that on subjects in experiments with the broken up and with the normal regimens of daily activity analogous results were obtained; i.e., a decrease in the time of a latent reaction period toward the end of the experiment, corresponding to from 0.4 to 0.30 and from 0.56 to 0.38 seconds. A decrease of response reaction of the latent period toward the end of the experiment indicated the fact of becoming trained to the test itself with a subsequent automatization of a motor habit. The significance of training and the lessening of time for response

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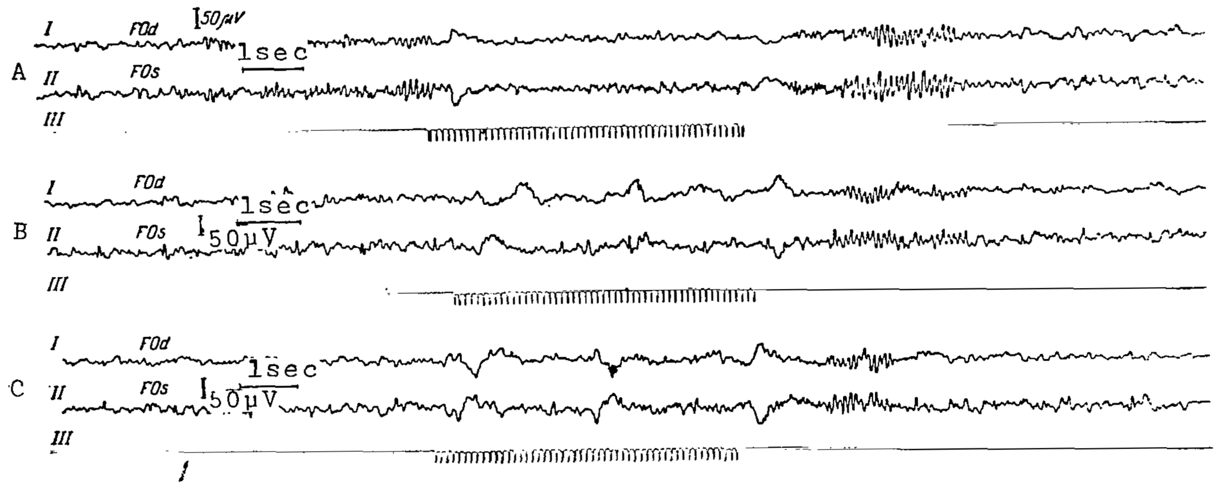

Fig. 13. Dynamics of Prolongation of Residual Reaction of the EEG of Subject G. in Isolation With Shifted Regimen of Daily Activity. (1) EEG, Forehead-Temple, Right; (2) EEG, Forehead Temple, Left; (3) Mark of Stimulus: (A) Prolongation of Exaltation of Alpha Rhythm on the 4th Day of the Experiment; (B) The Same on the 7th Day; (C) The Same on the 10th Day.

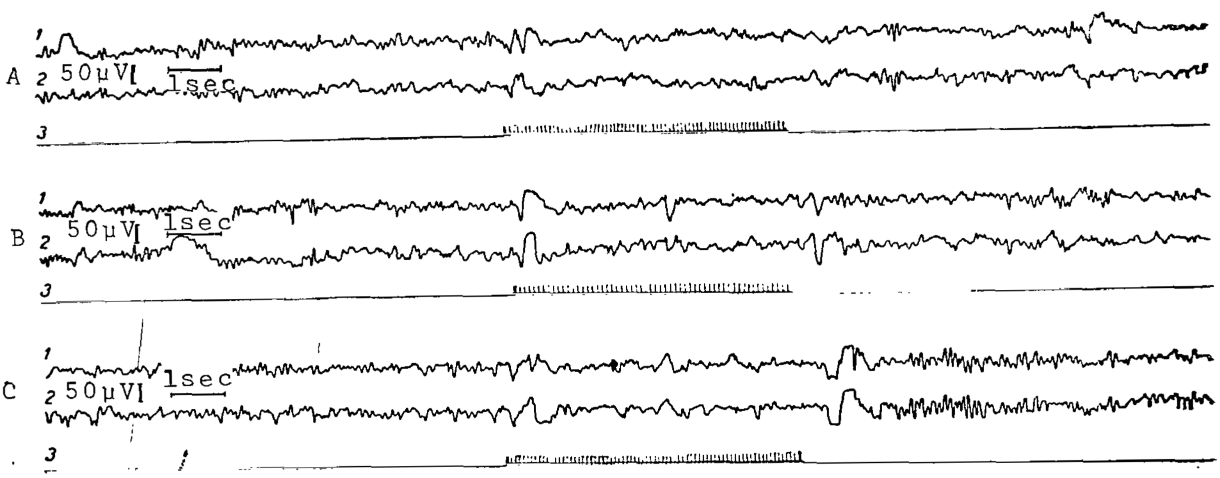

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Fig. 14. Effect of Accumulation of Stimulus on EEG of Subject N. (1) EEG, Forehead-Temple, Right; (2) EEG, Forehead-Temple, Left; (3) Mark of Stimulus: (A) Residual Reaction on First Presentation of Light Stimulus; (B) The Same on the Second Presentation; (C) The Same on the Third Presentation.

reaction was indicated earlier (A.V. Chapek, 1956; N.N. Gurovskiy, 1957, et al.). With a shifted daily activity regimen, the latent /117 period of motor response reaction, by the end of the experiment increased from 0.33 to 0.46 seconds (Fig. 15). An increase in the latent period was elicited probably by the onset of fatigue, the first signs of which appeared together with the development in the central system of inhibition processes (according to data electroencephalograph investigations). The fact of the appearance of fatigue as a result of the increase in time of the motor response reaction was noted in the investigations of other authors (A.N. Krestovnikov, 1954; O.G. Gazenko, 1955; E.I. Boyko, 1961, et al.). The investigation of freedom from interference testifies to the same fact. The level of freedom from interference allowed to the subjects in experiments with a shifted regimen of daily activity was lowered at the end of the experiments here. For analysis of the work with the number table, a great quantity "of releases of inhibition of differentiations" in relationship both to the calculation and to the correct indication of answer was seen (they gave the glack number instead of the red and vice versa). In addition, these subjects showed a strain in posture, mimicking and a great number of searching movements. The middle stage of work with the black and red tables appeared to be the most difficult for differentiation, where the number of similar stimuli sharply increased because of the repetition of ones, twos and threes (F.D. Gorbov, L.D. Cheynova, 1959). Investigations of resistance to distraction were accompanied by an increase in the general time taken for work /118 with the number table, and by a number of various errors (extraneous answers, illustrations, divergence and convergence of series, perseveration of figures, etc.) (Fig. 16). Despite the fact that the received data showed a certain difference between quantitative and qualitative expressions, the threshold level of distracting interference.

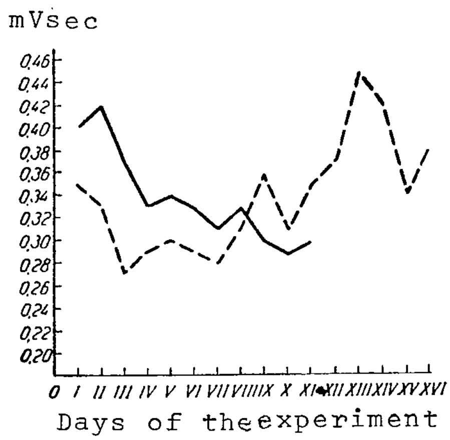

Fig. 15. Curve of the Latent Period Motor Response Reactions in the Subjects Under the Conditions of Isolation With Various Regimens of Daily Activity. Mean Arithmetical Latent Period: Solid Line - Changes Under Normal Regimen; Dotted Line - The Same Under Shifted Regimen.

lowered toward the end of the experiments with a shifted regimen. This lowering was connected with the onset of fatigue, to which the data from encephalographic investigations bore witness, as did an increase in the time of response motor reactions. In experiments with a broken up regimen, the quality of work with the black-red tables also decreased toward the end of the investigation. This was expressed in errors in various sections of the work with the number tables (Fig. 17). It is necessary to note that errors by the subject on the broken up regimen of daily activity is encountered more often than usual, but more seldom than with a shifted regimen. As far as the character of mistakes is concerned, in no way does it differ from those described above, and there was no tendency toward repetition. Thus, if one considers that frequency of mis- /119

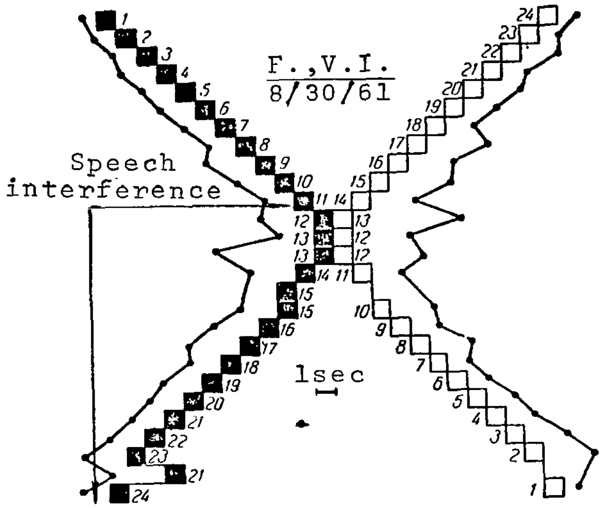

Fig. 16. Results of Work With Black-Red Tables in the Subject S (Shifted Regimen of Daily Activity) on the 10th Day of Experiment. Black Squares - Black Row of Numbers; Light Squares - Red Row of Numbers; Broken Line - Inter-Response Intervals of Time.

takes and their character appear as an objective expression of the level of the resistance to distraction then the latter was lower in the experiments with the broken regimen than on the normal regimen, but higher with the shifted regimen (Fig. 18). Results of the work of K.M. Bykov and A.D. Slonim (1949), E.I. Brandt and O.I. Margolina (1949-1954) showed that the problem in the preservation of work capacity during nocturnal occupations was inseparably connected with the daily rhythm of physiological functions. A.D. Slonim and O.P. Shcherbakova (1935) asserted that unfavorable subjective perception during night shifts was conditioned by the necessity of performing work on a background of lowered excitability of autonomic centers. Specially undertaken electrophysiological investigations of the functional condition of the central nervous system, by means of the curves of the bioelectrical reaction, showed that an extended stay of subjects under conditions of isolation with a shifted regimen of daily activity brought forth a lowering of excitability and reaction of the cerebral cortex: restructuring of bioelectrical activity to light stimuli was noted before the experiment (fifth to sixth second) and at the end of the investigation; restructuring of biopotential also appeared

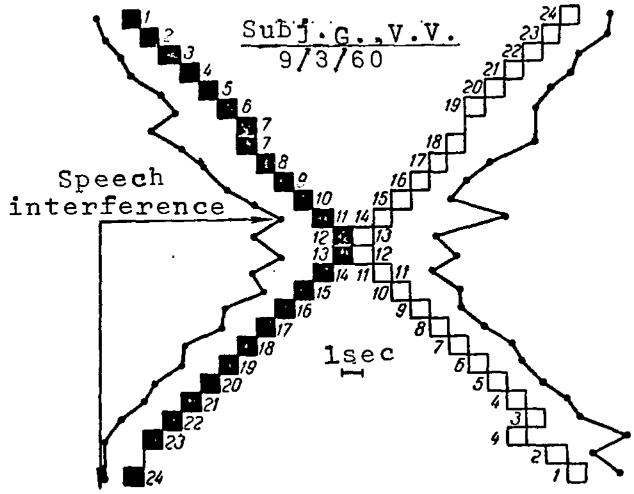

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Fig. 17. Results of Subject G's Work With Black and Red Tables on the 10th Day of the Experiment (Broken Regimen of Daily Activity). Designations as in Fig. 16.

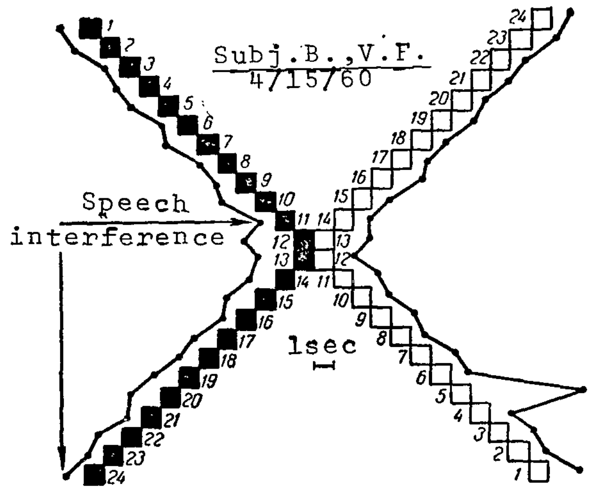

Fig. 18. Results of Subject B's Work in Black and Red Tables on the 10th Day of the Experiment (Usual Regimen). Designations as in Fig. 16.

(tenth to twelfth second). Distinct reactions were registered /121
only during the first recording; during the second and third they weakened or completely disappeared (Fig. 19). The data obtained attested to the fact that in experiments with isolation the subjects underwent not only the action of limitation of external afferentation and monotony of circumstances but also a regimen of daily activity influencing the neuropsychic sphere.

This circumstance can be taken into consideration for recommendations on structuring the astronautical day. For the organiza-

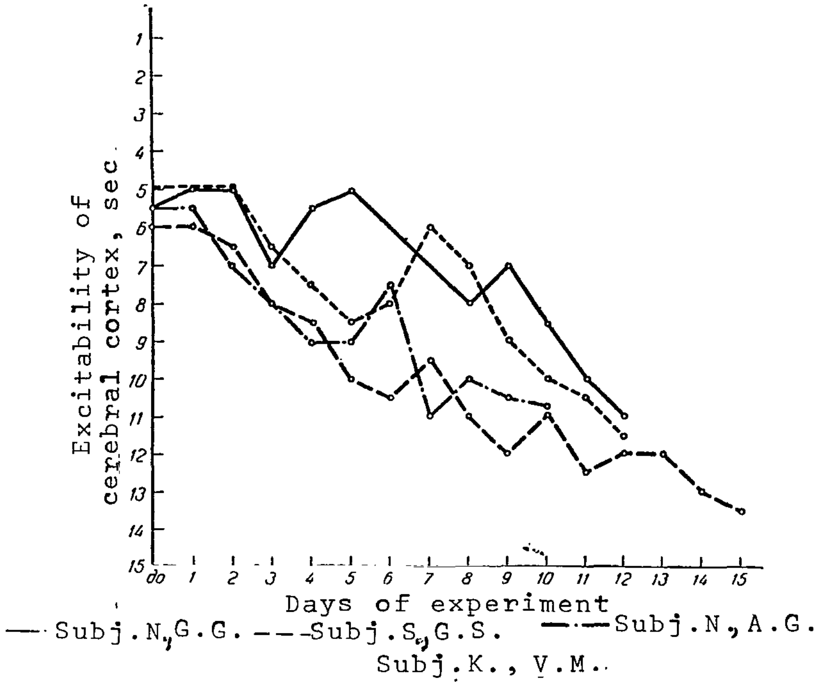

Fig. 19. Change in Excitability of the Cerebral Cortex in Subjects in Experiments in Isolation (Shifted Regimen of Daily Activity).

tion of a regimen of daily activity, it is necessary to consider, aside from the tasks which are presented by the flight, the characteristics of the environment and of the work area. /122

Uniformity and monotony of circumstances and weightlessness will cause sleepiness to develop. A transition from waking to sleeping, according to the study of I.P. Pavlov, is concluded after a series of hypnotic phases, which can be observed even during shallow sleep. In a series of phase conditions, for example during the so-called paradoxical phase, the sensitivity of the nerve cells rises to the action of very weak stimuli traces of formerly acquired impressions. They can be experienced by the astronaut as vivid dreams or can have the characteristic of eidetic images, externally similar to hallucinations. A characteristic property of eidetic images, as was shown by experiments in isolation, is that they are accompanied by a great number of associations and emotional reactions which are expressed in the reliving of joy, vexation, hostility, etc. (V.I. Myasnikov, 1963). As an example we can give the description of the eidetic ideas in subject D. during isolation experiments.

"So how do I feel? At times satisfied and at times melancholy. Some kind of internal wariness, which shows itself in that I'm always listening. Also, familiar melodies come to mind. Sometimes they come into my ears against my will. I hear the preludes of Rachmaninoff, Brahms, Ravel (Concerto for Violin and Orchestra) and of course the mighty Beethoven. Such clear Beethoven I've never heard before. Sometimes I lie down in the morning and I get up lazy, and in my ears there is Beethoven's Ninth Symphony. Inexpressible joy.

"Listening to Rachmaninoff, suddenly I distinctly saw the whole surroundings of the great hall of the conservatory, and I even hear the voice of the Mistress of Ceremonies. Operas go even better - /123 favorite arias and romances - and all of a sudden I imagine a violent dust storm that whirls chords and trivial fragments of a medley from the dance verand s of resorts. Frankly, they pursue me. There is one salvation from them--I begin to listen to what ever noise I can in the room--and all sound of music inside of me ceases."

Based upon the "inertia of neuroexcitation", these complex psychophysiological phenomena do not by themselves reflect any pathology, and are often encountered in children and more seldom in adults (Jensch, 1927; M.M. Cononova, 1929, 1934; L. Veygogskiy, 1930, et al.). In usual circumstances being subliminal, under conditions of silence and monotony they are produced completely spontaneously, but emotional tension, connected with a prolongation of the action of the indicated factors, made these impressions perceptible and externally similar to hallucinations.

Development of sleepiness and, as consequence of this, development of hypnagogic hallucinations or of eidetic images, can lead to lowering of the psychophysiological capacities of members of the crew from the point of view of rational distribution of attention and observations of instruments and of ships apparatus, of swiftness and precision in performing work operations and operating a ship in outer space.

Among the means of preventing the development of sleepy conditions and their consequences are the following:

rational construction of the interior of the cabin of the spaceship: the interior of the cabin, including in a stylized and generalized way a usual (terrestrial) environment, must act upon the psyche of the astronaut and be a means of association for forming necessary emotional background (V.V. Zefel'd, 1964);

creation in the cabin of various sources of "impressions": the interior of the cabin controlled from Earth, listening to tape recordings of various musical productions, watching films, etc.

The possibility of the development of emergency situations in space flight can elicit from people morbid reactions to such situations, disturbances, psychic excitation or depression, anxious thoughts. As a consequence of this there are disturbances of sleep and, in particular, insomnia. Extended duration and markedness of insomnia depends not only on the causes but also on individ- /124 ual personality traits. Therefore, insomnia can be conditioned by an insufficiency of sleep in certain circumstances or by its qualitative characteristics (depth of sleep, profusion of dreams, difficulties in falling asleep) in others. Disturbance in the quality of sleep in similar circumstances will lead to the onset of fatigue, with a consequent lowering of the capacity for work in crew members. Pathogenetic therapy must be reduced to soporific and neuropsychological preparations, tranquilizers, and ataractics.

Analysis of experimental data received in isolation under various regimens of daily activity permitted comparing the results of the investigation with each other and drawing several conclusions relative to possible functional deviations in the neuropsychic sphere of astronauts. This in turn defines a means of approach to solving the problem of prolonged preservation of a high capacity for work in the crew members of the spaceship in flight. Finally, the solution to the problem amounts to development of a rational regimen of work and rest. In this regard the problem of the operator's capacity for work can be decided, for example, by means of the creation of an artificial regimen of daily activity on the ship.

The possibility of the application of such a regimen of daily activity relies in part on necessity of the control of sleep in depth and prolongation. At the present time, this question has not been finally solved. However, regardless of the means (application of pharmacological preparations of directed effect or with the aid of electricity and radio), controlled sleep will permit the swift mobilization of the organism for performing the tasks assigned in advance by the flight program (awakening at a given time, and a rapid beginning of work activity), and a swift waking and falling asleep will be possible in periods not connected with steering the spaceship or concluding special investigations preassigned by the flight program.

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THE CAPACITY FOR WORK AND THE CONDITION OF HIGHER NERVOUS ACTIVITY UNDER VARIOUS LIFE REGIMENS

M. A. Gerd

ABSTRACT: The results of various tests of mental and physical reflexes during a two-week experiment with three subjects are presented. Round-the-clock watches were established and results are given presenting comparisons of responses of subjects according to the shifts worked.

The present essay presents the results of the study of the human organism's process of adaptation to life according to several variants of regimen. An experiment was carried out simulating several conditions of a space ship with a crew of three people whose assignments were organized to cover all aspects of the necessary work, in particular the round-the-clock watch. /126

It is possible to assume that restructuring of the daily periodicity of sleeping and waking, which was established by evolution, depends on a number of causes and, to a certain degree, on how quickly during the experiment the sleep of the subject normalizes and how quickly restructuring of their life activities for productive wakefulness at night proceeds. Written and oral interrogations were carried out in order to characterize sleep and wakefulness. The intellectual capacity for work in the experimental period was evaluated with the aid of a number of methods. Investigations using various methods were carried out during the first and second watch from the moment of awakening: consequently in the night, in the morning, in the daytime and in the evening period of the astronomical day. By means of a written account, subjects were directed to write out the multiplication of three-digit numbers and to orally recite the mental multiplication of two-digit numbers (examples were selected on the basis of equal difficulty). At the time of one investigation, the subjects solved 10-20 examples, which permitted elaborating the obtained data by means of variation statistics and presenting them in the form of mean arithmatic values, indicating the mean number of mistakes and mean quadratic deviations.

In an association test, during 2-3 minutes at 10-15 second intervals, the experimentors called out to the subjects 20 words--nouns signifying objects of common occurrence not having any logical interrelationship. The subject had to respond, without pausing, with the first word that came to mind. The reaction speed was considered and the quality of the oral response was evaluated.

In order to study operations demanding coordination of the fine movements of the hand, the subjects were presented the task of fastening parts with bolts and nuts. They had to complete 70 operations at a fast tempo, each operation consisting of 5 stages: to take the bolt from a box, place it in the opening, take out a nut, put it on the bolt and tighten it. Chronometric observations permitted recording the times for completion of each operation, mistakes and the types of mistakes. /127

The character of the subjects' higher nervous activities was defined before the experiment and immediately after its end. The force of the processes of excitation and inhibition, their dynamicity and the predominance of one process over another were investigated with the aid of the methods of V. D. Nebylitsyn (1961).

The magnitude of the preliminary EEG reflex in response to a 5-second exposure to sound at a frequency of 200 imp/sec was determined. The amount of alpha rhythm depression (in seconds) changed with the first, second and third presentation of sound. They registered the speed of disappearance of alpha rhythm depression with the repetition of the sound (to a preliminary and full increase), that is, the alpha rhythm depression was absent three times. A conditioned reflex to a sound of 200 imp/sec in frequency was developed by means of a simple (light) reinforcement, and also a conditioned reflex to the same sound with an activating reinforcement, for which a 10 second exposure of photographs was used (as an index of expressivity of conditioned EEG reflex, the amount of alpha rhythm depression in seconds upon the presentation of an isolated sound was used). The development of differentiation was carried out. An intermittent sound at a frequency of 100 imp/sec was used as a differentiating stimulus presented after 2-5 combinations of sound at a frequency of 200 imp/sec with an activating reinforcement (as an index of the process of development of differentiation, a number of combinations was used until the first of three instances of the disappearance of alpha rhythm was received).

The study of emotional tension immediately after the experiment was carried out with the aid of a special boom 4 cm wide and 2.5 m long, which was located at a height of 4 cm from the /128 floor. The subject had to walk along this apparatus in time with a metronome at a speed of 2 paces per second (the length of one pace is 45-50 cm). The loss of balance (wavering and staggering) was measured, and with the aid of an electrocardiograph the pulse rate, breathing and the general speed of travel along the boom (in seconds) were recorded. The degree of emotional tension was detected by raising the boom to a height of 40 and 70 cm from the floor.

Preliminary experiments gave the following results: significant increase in cardiac systole; holding the breath; and changes in the speed of walking which arose when the subject was afraid to go along the boom. The condition of emotional tension had a negative influence on the coordination of movements. A worsening of emotional tension in turn strengthened the feeling of stress and fear in moving along a narrow boom at a relatively great height.

Therefore conditions of the coordination of movement also were used as an index of emotional tension.

Results of the above given experiment showed the following: in subject LI, who slept by night and remained awake by day, sleep was normal: he fell asleep relatively quickly and sleep proceeded without dreams.

In the waking period the subject felt well enough in the first half of the experiment. At the end of the experiment, he began to complain about the appearance of fatigue and general sluggishness; easily performed aspects of activity began to demand willpower; the desire to be occupied with scientific material diminished; and weak noises and slight maladjustments irritated him. L. I. explained the appearance of these phenomena as due to the extended stay in the chamber.

The speed of completion of intellectual operations at the time of first and second watches during the experiment fluctuated insignificantly. Some statistically unverifiable retardation was noted only at the very end of the experiment (a natural slowing down in the written count was registered on the 13th day in the first watch). During the experiment, the subjects performed separate intellectual operations. They had approximately /129
uniform speed, and only at the end of the experiment did a great inequality appear in the speed of arithmetic operations: LI solved some problems relatively quickly and the others unusually slowly. Under statistical analysis of the received data this was reflected in various amounts of deviation from the mean arithmetic value.

After the end of the experiment, L.I. worked swiftly and made, for him, an uncharacteristically large number of errors. In the conduct of the subject an unusual talkativeness was noted, and his movements were less precise.

Investigation by electroencephalograph carried out 20 minutes after the end of the experiment showed an increase (2.3 times) of alpha rhythm depression upon the first presentation of sound. The process of primary extinction of "orientational" reactions took place more quickly (1.5 times) than before the experiment. However full extinction (up to the absence of alpha rhythm depression for 3 times in succession) could not be reached. Conditioned alpha rhythm depression was developed by means of a greater use of the combination of sound with light (2.9 times more than before the experiment). The amount of conditioned alpha rhythm depression with a simple and activating reinforcement after the experiment was markedly decreased (corresponding to 2.1 and 2.4 times), and beginning with the sixth presentation of stimulus (with simple reinforcements) and with the eighth (with activating reinforcements), alpha rhythm depression disappeared. Differentiation could not be developed because of a lack of conditioned alpha rhythm depression.

In traversing the boom, a retardation of motion was recorded (before the experiment, 4.8 seconds; afterwards, 5.2 seconds) and an increase in the pulse rate was noted (from 75 to 81) along with retention of breath (an increase in the number of losses of balance) (Table 15).

The subjects (G.M. and N.S.) who lived according to a regimen of waking at night and sleeping at an unaccustomed time complained about poor sleep during the 1-7th days of the experiment: they fell asleep with difficulty, often awoke during sleep, and after sleep they did not feel cheerful and rested. After 9-10 days, subject /131 G.M. was able to sleep somewhat better, and after 10-12 days his sleep normalized. For subject N.S. a sleep was restless right up to the end of the experiment.

At the time of the watch, according to chronometric data, in the beginning the subjects often dozed and even slept in the night and in the early morning hours. On the 10th day, this condition almost fully ceased.

The data of the investigation which is related to characterizing condition of wakefulness may be given as the following: at the beginning of the experiment, G.M. and N.S., completing their assignments during the night hours, complained of sleepiness and a sluggishness of intellectual operations connected with it. Upon the completion of assignments in the day hours, they indicated an absence of feeling in good shape, sluggishness and sometimes, on the other hand, tension, which in their opinion was a consequence of insufficiently good sleep. Beginning with the second half of the experiment, and especially at the end of it, the subjects noted that during the night time it became easier to complete difficult operations than during the day, and it was quieter to work. For subjects G.M. and N.S., a general sluggishness and tension in the completion of intellectual operations increased with the duration of the experiment. Complaints appeared about quick fatigability, and pronounced negative attitude toward the completion of some assignments was noted. The subjects explained the general worsening of psychological conditions as a result of the extended stay under the conditions of the experiment.

The data received in studying the intellectual capacity for work permitted conclusions to be drawn on the high quality of work operations. With the association experiments, primitive oral responses (interjections, repetition of word signals, refusal to respond) almost were nonexistant. The number of mistakes in counting

TABLE 15

Subj.	Before the Exp.				After the Exp.			
	1 Time		2 Times		1 Time		2 Times	
	Pulse Rate	Time, Sec	Pulse Rate	Time, Sec	Pulse Rate	Time, Sec	Pulse Rate	Time, Sec
	Height 4 cm from the Floor							
G.M.	79	5,7	—	—	115	5,8	125	4,8
N.S.	78	6,6	71	5,3	89	6,3	81	5,2
	Height 40 cm from the Floor							
G.M.	78	5,3	75	5,7	100	6,6	115	6,0
N.S.	78	5,9	91	5,8	97	8,0	107	7,8
	Height 70 cm from the Floor							
G.M.	86	5,5	90	5,3	125	8,1	115	8,1
N.S.	93	5,7	99	5,9	115	7,5	105	6,5
	Height 4 cm from the Floor							
	No. of Hesitations	No. of Slips	No. of Hesitations	No. of Slips	No. of Hesitations	No. of Slips	No. of Hesitations	No. of Slips
G.M.	0	0	0	0	1	0	2	0
N.S.	0	0	1	0	3	1	2	0

increased in only one instance (with subject NS in the written count). /131

The speed of the intellectual operation of subjects G.M. and N.S. in the period of the experiment was markedly slower than before the experiment. A retardation of reaction speed in the course of the experiment was observed in the majority of instances; however, it was not statistically verifiable.

The dynamics of change in speed of intellectual operations permitted the conclusion to be drawn that the completion of tasks in the beginning of the experiment was retarded more than in the latter period of the experiment. In a number of circumstances such a retardation was specifically verifiable. A comparative analysis of the speed of all instances of problem solving shows that in the beginning of the experiments, for the completion of one task the subjects accomplished arithmetic operations first relatively quickly and then relatively slowly. Similar inequality in intellectual /132
operation was especially marked in the work of the subjects during the night period.

At the end of the experiment, in a number of instances an increase in reaction speed and a disappearance of instances of especially prolonged completion of separate tasks was recorded (such dynamics of changes were not observed in the change in speed of the count of subject N.S. evidently for this subject during the experiment the gradual acceleration of data on intellectual operations was connected with training).

Analysis of the speed of completion of work operations in the beginning of the experiment in the first and second watch showed the following: in the first watch with the combination of two relatively favorable factors (evening hours and between 4-6 hours after sleep) subject G.M. completed the task more quickly than in the second watch. During the middle of the experiment (6-11 days) in a number of instances G.M. completed the necessary operations more quickly in the second watch than in the first. At the end of the experiment (13th day) the mean reaction time in the first and second watch was approximately the same.

With subject N.S. in the beginning of the experiment (second and third day) the speed of reaction in the first watch (by night but immediately after sleeping) was markedly slower. In addition this subject, having fulfilled the task, solved separate problems especially slowly. In the second watch, which took place early in the morning against the background of noticeable fatigue (13-14 hours after sleeping), the reactions speed also was not great. At the middle and the end of the experiment (6-13 days), the subjects worked faster, sometimes in the first watch and sometimes in the second watch, and on a number of occasions the speed of reaction was approximately equal.

Completion of the task of fastening planks with nuts and bolts was slow at the beginning of the experiment. The subjects completed these actions especially slowly at night. During the middle and at the end of the experiment, the work was completed faster; moreover, in the first and second watch the subjects worked approximately with equal speed. Coordination of fine movements of the /133 hand for subject G.M. were markedly worsened; toward the end of the experiment he dropped the nuts and bolts and made extraneous movements.

Right after the end of the experiment, G.M. and N.S. performed the necessary actions more quickly, but in addition an especially large number of mistakes were recorded for them. The qualitative analysis of these mistakes permitted defining them as considerable (the subject forgot the multiplication table, and during the completion of the associative experiment, primitive oral responses appeared).

In addition, the behavior of G.M. and N.S. in the times of the observation differed from the usual: the subjects talked aloud about several groups of assignments, they forgot the results of their activities, talked to the experimentor, tried to make jokes. Upon interrogation, G.M. and N.S. showed a happy and excited condition. They said that they worked easily without any tension and did not feel tired.

Investigation of nervous system reactions by electroencephalograph was carried out only for N.S. (G.M. was the type of person who does not raise an alpha rhythm on an EEG).

Forty-five minutes after the end of the experiment, for subject N.S. no changes in the amount of orientation reaction were shown in comparison with similar data obtained before the experiments. However, on the second and third presentation of sound, i.e., 9 and 14 seconds after the first presentation, the amount of alpha rhythm depression sharply diminished in comparison with its volume before the experiment (on the second presentation, by 7 times, and on the third by 1.8 times). The process of primary extinction of orientation reaction was realized more quickly (by 2.5 times); however, a full extinction was not reached until after 25 presentations of sound. Conditioned alpha rhythm depression was developed by a greater (2.5 times) number of combinations of sound with light before the experiment. The amount of conditioned alpha rhythm depression diminished with a simple (3.6 times) and with an activating reinforcement (2.3 times). Differentiation could not be worked out. Data (Table 15) received by movement of the subjects along the boom at various heights, permitted the registration of greater fluctuations in the speed of passage along the boom then before the experiment. The movements became irregular; the subject first ran then began to go very slowly, stopped for a long time and could not take the next step. Pulse became more frequent, and its /134 increase on the high boom was markedly more significant. In the words of subject G.M., traversing the boom at a height began to elicit greater apprehension than before the experiment. On the day following the end of the experiment, the speed of reaction was approximately the same as before the experiment; the number of mistakes sharply dropped and the behavior of the subjects did not show any noticeable deviation.

Materials obtained in the study of the capacity for work of the first subject (L.I.), on the regimen of life which consisted of a sleep time corresponding with the night period of the day, indicated an unerring and swift completion by this subject of the various experimental tasks. A certain retardation of reaction at the end of the experiment evidently was connected with the fatigue which developed during the course of the experiment and the condition of general sluggishness. During the course of the experiment, the absence of retardation of reactions in the second watch, in comparison to the first watch, witnessed the fact of the preservation of normal work capacity of the subject in the period of waking. One of the essential causes determining a good work capacity for L.I. is good sleep.

Materials obtained in the study of the work capacity of G.M. and N.S., who were awake in the nighttime, during the early morning and the late evening hours (under the conditions of sleep in unusual time of day), indicated the retardation of almost all reactions. This signifies that an essential change in regimen of life, not influencing the quality of work, led to a retardation of intellectual operations.

An especially great retardation in speed of reaction in the first half of the experiment indicated that a sharp transition from a normal regimen of life to the experimental one significantly reflected upon the work capacity of the subject. A worsening of the processes of sleeping and waking during such a transition evidently can be viewed as one of the causes of the worsening of work capacity. In all probability the daily periodicity also played a certain role, according to which the night time appeared to be more productive for intellectual operations. Tendencies toward the normalization of the speed of reactions under the conditions of improving sleep and the condition of wakefulness evidence the beginning of the process of acclimation.

It is known that the duration of alpha rhythm depression and the orientational reaction can be treated (V.D. Nebylitsyn, 1966) as an index of the excitory processes. The increase in alpha rhythm depression which was manifested in one of the subjects permitted the assumption of a greater intensity of the excitation process during the first exposure to sound than before the experiment. However, a swift fall in the amount of orientational reaction after 7-12 seconds (in the first and second presentation of light) indicated a sharp drop in its intensity. A primary extinction of orientational reaction which was swifter than before the experiment /135 and, conversely, the retardation of extinction before receiving, for three times in succession, an absence of alpha rhythm depression, evidences on the one hand the greater intensity of the inhibitory process, and on the other the low level of its dynamicity. It is known that rapid formation of a conditioned reflex is a function of the excitory process (Ye.N. Sekalov, 1958, et al.), and consequently, if inhibition is markedly lower than excitation in a person, his reflexes will form quickly; if inhibition predominates slowly. Rapidity in the process of EEG reflex development permitted a conclusion to be drawn about the significant post-experimental shifts in relation to the processes of excitation and inhibition on the side of the predominance of excitation. The lessening (in comparison with the data obtained before the experiment) in the amount of conditioned reflex and its swift disappearance witness the exhaustability of the excitation process. The fact that we did not succeed in developing differentiations, since before the experiment they were recorded quickly, indicated a weakening of the inhibitory process; it is known that the speed of the formation of differentiation, according to the data of N.A. Podkopayev (1954) and M.I. Mayzel' (1956), is an index of the strength of the inhibitory process.

Thus the condition of higher nervous activity right after the experiment was characterized by the predominance of the excitory process, and in addition the process of excitation was not as strong as before the experiment: it rose quickly, but having risen was swiftly extinguished. The inhibitory process was also weakened.

Evidently, such a condition of the higher nervous activity of the subjects has an effect upon their work capacity. The appearance of haste of actions, increase in the number of mistakes and absence of proper control in a serious relationship to the work above the experimental assignments can be considered consequences of this. A shift in the relations between the processes of excitation and inhibition, the weakening and a swift exhaustion of excitation, a weakening in the process of inhibition can also explain several instances of the behavior and mood of the subject. Materials received in the study in which the subjects walked along a boom bore witness to the fact that the participants in the experiment of this period were under a condition of emotional strain.

The fact that the given phenomena took place only right after the experiment and then disappeared evidence the connection of the above-described condition with the post-experimental period.

In summary, it is possible to draw the conclusion that work capacity on the regimen of life with sleep during the night time in the course of the experiment changed insignificantly, and the changes were connected with the prolonged action of the experimental conditions.

Change in the work capacity with an essential change in the life regimen of the participants in the experiment basically was expressed by retardation of reaction. More significantly, it was expressed in the beginning of the experiment (with a sharp transition to life according to the experimental regimen); later the speed of reactions increased. At the end of the experiment a certain retardation of reaction was observed which was connected, evidently, with the extended stay of the subjects under the conditions of the experiment.

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DYNAMICS OF THE INTELLECTUAL CAPACITY FOR WORK AND THE CONDITIONS OF HYPODYNAMIA, ISOLATION, AND ELEVATED TEMPERATURE IN A HERMETICALLY SEALED CHAMBER

Y.M. Krutova

ABSTRACT: The article deals with three experiments on the effects of isolation in a hermetically sealed chamber on memory and mental concentration.

On prolonged space flights, man will be subjected to the influence of specific conditions--weightless, hypodynamia, insufficiency of afferentation, etc. Therefore work activity under these conditions will differ structurally from activity under the usual terrestrial conditions. Thus, for example an astronaut's monitoring activity will be characterized by its monotony, uniformity and comparative poverty of external impressions (almost unchanging position of the star-filled sky, lack of external sound stimuli, etc.). Therefore it is necessary to maximally approximate the actual conditions of life activity in flight in terrestrial laboratory experiments and to observe carefully the dynamics of intellectual and physical work capacity under the influence of these and other unfavorable conditions.

The majority of foreign and native investigations have been dedicated to the study of the influence of the conditions of isolation (hypodynamia, lowered and raised barometric pressure in the chamber, hypoxia, etc.) on man's physical capacity for work. Thus, Levy and Thaler note that under the conditions of strict isolation, the work capacity decreased and neuromuscular tension increased as does a feeling of depression. A worsening of these conditions progresses as the stay in the chamber is prolonged.

Such kinds of changes are indicated by Gerathewhol (1959), Hartman (1962), Ewrard and Henrotte (1959). Lewis (1959) showed experimentally that under conditions of inadequately strict isolation the work capacity also lowered.

Analogous data were obtained by the native investigators (M.B. Umarov, A.B. Lebedinskiy, S.V. Levinskiy, Yu.G. Nefedov, F.D. Gorbov, V.I. Myasnikov, V.I. Yazdovskiy, et al.).

In investigations dedicated to the study of the influence of /138
hypodynamia (Gerathewhol, N.A. Agadvhanyan, A.G. Kuznetsov, et al.), along with a worsening of physiological work capacity, a lowering of tension and the retardation of the thought processes were noted.

It must be said, however, that to date the question is unanswered as to how intellectual work capacity and the psychic functions change dynamically under the conditions of isolation, hypodynamia and unfavorable atmospheric temperatures in a hermetically sealed chamber.

Among native and foreign research projects, investigations dedicated to this problem are not represented.

The aim of the present investigation is to study the influence of limited mobility and partial sensory isolation, at an elevated temperature in a hermetically chamber of small volume, on the intellectual work capacity and psychic functions of the subject (thought, memory, attention).

We carried out three experiments. The aim of two 15-day experiments was the study of influence of partial sensory isolation and hypodynamia on the concentration of attention, memory, and intellectual work capacity of the subject. The investigation was carried out in a hermetically sealed chamber of small volume (5 m^3) at a temperature of 20-23°C, a humidity of 45% and a maximum carbon dioxide content of 0.5-0.8%.

In the first experiment the subject was a scientific colleague (32 years old) with an advanced education and good physiological preparation, who had taken part in analogous experiments repeatedly. The subject in the second experiment was an engineer 29 years old who was participating in his first experiment. Communication with the subjects was established with the aid of a microphone. The third experiment was dedicated to studying the influence of elevated temperature and humidity on those same processes and capacity for work: the four subjects studied were placed in a specially equipped chamber. The temperature in the chamber was 38-40°C and the humidity 66-70%. Each day two subjects stayed in the chamber for 4 hours. The investigation was carried out over 4 days, so that each pair was in the chamber 4 hours per day.

Studies for the first two 15-day experiments were carried out before the experiment, four times during the experiment (on the 2nd, 8th, 10th and 14th day) and after the subjects left the hermetically sealed chamber. In the third experiment, daily studies were carried out before beginning the experiment and two hours after the subjects entered the hermetically sealed chamber.

The regimen of life activity in the two 15-day experiments was /139
not altered and remained normal. The subjects slept during the usual night and began work at 9 A.M. After the morning hygienic procedures and a medical examination, they completed mental and physical labor and alternated this with active rest following a definite schedule.

The control group consisted of 15 subjects who had passed a careful medical examination. All of the subjects--doctors and engineers up to 30 years of age--were occupied with analogous activity but under normal circumstances. Data from the investigation of the subjects in the control group gave the possibility of comparing and evaluating those changes in mental processes (intellectual work capacity) which appeared under the conditions of limited mobility, isolation and warmth.

The following methods were used for studying an intellectual capacity for work.

In order to study productivity of intellectual activity and tempo, the complex and altered Krepelin test was used (linear addition and subtraction of numbers for the same time interval). In addition, productivity was judged according to the numver of completed operations and the quality of their completion (the number of incorrect solutions).

Concentration of attention was studied with the aid of a correction test. Evaluation of concentration was made according to the presence or absence of mistakes upon the completion of the tests. The time for the completion of the test, how quickly the subject concentrated his attention on the object, also appeared as a supplementary index of the character of attention concentration. In order to investigate memory, concrete and abstract words were used. The retention of new material and the strength of memory was judged according to the character of response, immediately after the presentation and after a definite interval of time.

The thought processes of the subjects were studied with the aid of association tests (variant--to respond with a word of opposite meaning). The characteristics of the subjects' thought activity /140
were judged according to the nature of the association and the time for the response.

In the first 15-day experiment in the hermetically sealed chamber of small volume, subject A's productivity of intellectual activity worsened irregularly, reaching its lowest point when he left the chamber. If the dynamics of change in intellectual productivity and the tempo are traced, then it appears that the greatest lowerings fall on the 2nd, 8th and 10th days of the experiment (Fig. 20). It was precisely on those days that the number of mistakes in the completion of the assigned operations increased noticeably. The speed of assignment completion decreased. The time required for the completion of specific intellectual activities increased 1-1/2 times in comparison with the baseline data.

On the tenth day, the speed of subject A's intellectual activity slowed down even more, and productivity fell off irregularly.

On the fourteenth day in the hermetically sealed chamber, a rise in intellectual productivity was observed; the number of incorrect solutions diminished, and the tempo of activity became more regular. Upon interrogation of the subjects it appeared that this took place because of a "finish" effect, a mobilization of compensatory capabilities of the organism.

"I'm accustomed to the conditions of a hermetically sealed chamber, he states", but I have to strain my will /141
greatly in order to complete assignments. I tried to complete it carefully because I knew there was still one more day of my stay in the chamber. This urged me on".

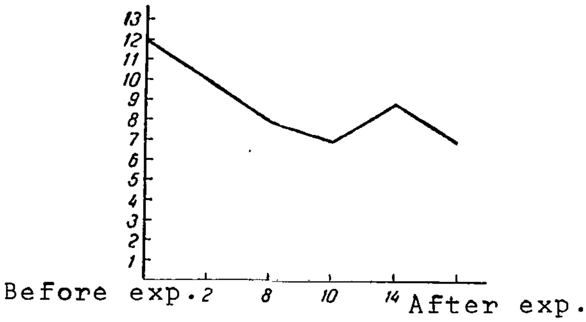

Fig. 20. Change in Productivity of Subject A's Activity. Along the Axis of Abscissa, Days of the Experiment; Along the Ordinate Axis, Number of Completed Intellectual Operations.

The latent response reaction time in the associative experiment for subject A, on the second and eighth day, was increased almost twice in comparison with the original data and the data of the control group.

The dynamics of change in this subject's concentration were almost analogous to the change in productivity of intellectual activity, Figure 21. Attention concentration lowered, beginning the second day in the hermetically sealed chamber, reaching its lowest point on the 8th day. On the 14th day, an improvement was observed.

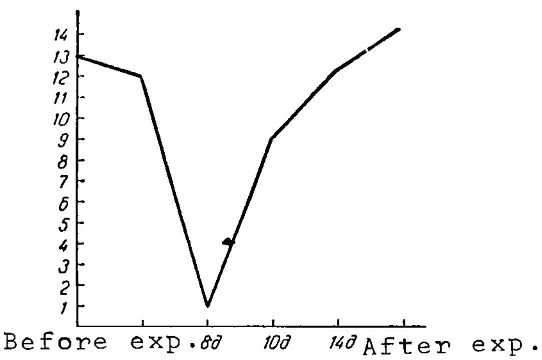

Fig. 21. Change in Attention Concentration for Subject A (First Experiment).

The memory of subject A during the entire experiment was almost unchanged.

An insignificant lowering was observed only on the second day in the chamber. For the remaining days, the memory function remained unchanged.

Indices of attention concentration and of memory after leaving the hermetically sealed chamber improved insignificantly in comparison with the baseline data, but productivity of intellectual activity lowered. At the end of the comple- /142
tion of the assignment, a sudden tendency to fatigue appeared (curve of productivity lowered). It must be said, however, that investigation after subjects left the hermetically sealed chamber was not carried out on the first, but on the third day. Before the investigation, the subjects had active daily rest.

In the second 15-day experiment (Subject B), dynamics of change of psychological functions and productivity of intellectual activity in the daytime was close to the data received in investigation of subject A (first experiment) according to this index.

On the second day in the hermetically sealed chamber of small volume, as with first subject his productivity of intellectual activity worsened in comparison with the baseline data (Fig. 22). There were more wrong solutions in the completion of intellectual operations, and the usual time for completion of separate activities lengthened.

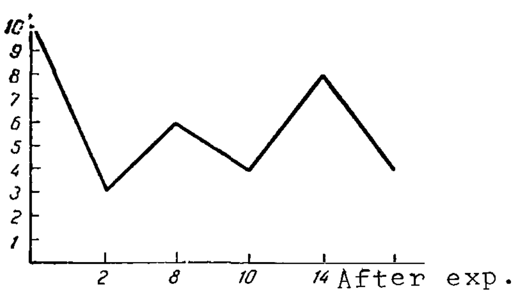

Fig. 22. Change of Productivity of Intellectual Activities of Subject B.

On the eighth day, productivity of intellectual activity also lowered, although less than on the 2nd day.

A more pronounced lowering of productivity was observed on the tenth day.

In all the cited days, attention concentration of the subject also dropped (Fig. 23). The time for the completion of the correction tests lengthened.

In association tests, an increase in latent response reaction time appeared, but associations were adequate.

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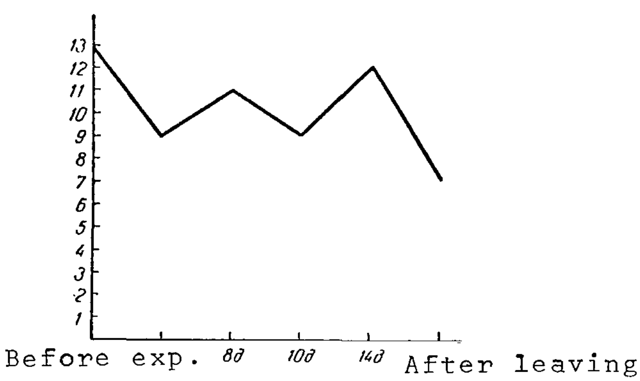

Fig. 23. Change in Attention Concentration of Subject B (Second Experiment).

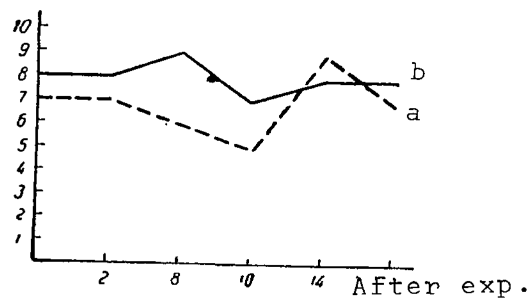

Fig. 24. Dynamics of Change in Memory of Subject B. Along the Abscissa, Days of the Experiment, Along the Ordinate, Number of Remembered Words: (a) Abstract Words; (b) Concrete Words.

The memory process slowed in time. The subject asked that the words he memorized be presented more slowly, pleading difficulty of memorization. While subject A's memory during the experiment suffered almost no changes, the second subject demonstrated a marked irregular lowering of memory (Fig. 24). It is characteristic that for him, as for the first subject, on the fourteenth day in the hermetically sealed chamber both productivity of intellectual activity and concentration of attention improved. He completed intelectual operations qualitatively better, and the number of wrong solutions was sharply curtailed. However, the tempo of intellectual activity lowered, and the time for completion of specific operations was lengthened. Subjectively subject B evaluated this: "I am used to conditions of the hermetically sealed chamber. I feel well. However slowly,I am completing your requirements with effort, and I am trying to complete them well." /144

After leaving the chamber (indices were recorded on the next day), productivity of intellectual activity appeared to be lower. The tempo of completion of intellectual operations had slowed sharply and was irregular in comparison with the baseline data; the subject was easily fatigued. Attention concentration and the process of mental concentration slowed down. Indices of memory were analogous to the data obtained before the experiment.

It must be noted that for subject B an even more pronounced retardation of the thought process was observed. Latent response reaction time increased. Associations were inadequate in the majority of cases. The objective data are supported and self-explanatory by the results. The subject alleged that it was hard for him to think; he became "wooden"; he noticed dizziness and difficulty in concentrating.

Analytical data of indices of change in the psychological processes and productivity of intellectual activity for subject B evidence a slight, pronounced negative influence of the experimental conditions.

Study of the data of the investigation obtained in experiments on the effects of temperature indicate that the influence of elevated temperature and humidity in the chamber was different on each of the four subjects taking part in the experiment. This difference is explained evidently as typological characteristics of the subjects, by the training to similar kinds of effects, as well as in relationship to the performance of manual labor.

For two subjects (C and D) deviations were not so noticable. For two others (E and F) the influence of the experimental conditions was sharply pronounced.

The first day of the investigation, the number of mistakes made by subject C notably increased, and the performance of the correction tests and attention concentration worsened in comparison with the baseline data. The time for completion of the tests was unchanged. /145

On the second day the same body temperature (38°), the temperature in the chamber (39°), humidity (66%) the time for the completion of the correction tests was extended, but the amount of mistakes diminished. The number of memorized data in the first day of the subject's stay in the chamber, at a temperature of 39°, diminished in comparison with the original data by 30-40%. Intellectual productivity of Subject C on the first day, in comparison with the baseline data, lowered. The tempo remained irregular. The time necessary for the completion of intellectual operation increased.

In the association tests, response reaction time was retarded; associations were adequate.

For Subject D, who was in the chamber with Subject C, almost analogous changes were observed.

On the first day there was also a worsening in the attention concentration and an increase in the times for completion of correction tests. On the second day, the effect of the elevated temperature and humidity proved to be less. Attention became more concentrated; the number of mistakes dropped in the completion of the correction tests.

Memory for the first subject, who was in the chamber at the same time, worsened. The amount of material he remembered dropped by 30% on the first day in comparison with baseline values and the data of the control group and on the second day by 20%. In this case, as we can see, the data of the investigation of memory by days for both subjects were almost analogous. Analysis of data of productivity of intellectual activity for subject D showed that it lowered. Moreover, the tempo of activity became irregular and lowered toward the end of the stay in the chamber, showing a rise in fatigue.

If we compare the data of intellectual capacity to work by /146
days, then the capacity for work on the first day noticably worsens. The qualitative rather than quantitative aspect especially suffers: there were more mistakes in the completion of the test. The thought processes were retarded, the latent response reaction time in associative experiments increased in comparison with the original data, but the associations were adequate.

Analysis of the data received in the study of the psychological functions of the second pair of subjects, E and F, and the productivity of their intellectual activity, evidences a more expressed influence on them of the conditions of elevated temperature and humidity in the chamber. Thus the productivity of intellectual activity of subject E sharply lowered qualitatively on the first day. The quality of completed thought operations lowered even more sharply on the second day. The number of wrong answers increased by three times in comparison with the baseline data and the data of the control group, and pronounced fatigue increased (the curve of productivity lowered at the end of the completion of the task). Attention concentration fell sh ply, and the number of mistakes increased 10 times (in comparison with the original data) on the first day of the experiment, and 8 times on the second day. Memory remained stable on both in the first and second day of experiment. Response reaction time in the association tests changed only slightly.

For subject F, who was paired with subject E, attention concentration on the first and second day of experiments also dropped sharply. On the first day it dropped by 3 times and on the second day by 2 times in comparison with the original data.

Productivity of intellectual activity of subject F dropped sharply both on the first day of the investigation and on the second. Tempo for completion of tasks was retarded, and pronounced fatigue appeared.

Memory, as for subject E, did not undergo essential changes.

In the associative experiments latent response reaction time increased doubly; associations were often unreasoned and inadequate. It was characteristic that even the autonomic functions for the two latter subjects (E and F) during the experiment also changed sharply.

Thus, analysis of the data shows that under the conditions of /147
a hermetically sealed chamber of small volume with partial sensory isolation and limited mobility, with the temperature in the chamber not more than 20-22° and humidity not more than 45%, productivity and intellectual activity for both subjects sharply fluctuated by day and worsened toward the end of the stay in the chamber. A pronounced worsening of productivity, intellectual activity, and also of attention concentration and thought was noted for both subjects on the second day in the hermetically sealed chamber, on the eighth day for subject A, and the tenth day for subject B.

Conditions of the partial sensory isolation and hypodynamia show a greater negative effect on the thought processes of the subject on his productivity of intellectual activity and on his concentration of attention.

The thought process under the experimental conditions was retarded in time and worsened qualitatively.

Under the conditions of a hermetically sealed chamber with elevated temperature and humidity, a more pronounced worsening in intellectual capacity for work, attention concentration, memory and retardation of thought processes was observed. Thus the intellectual work capacity lowered quantitatively on the average by 2 times.

Attention concentration worsened on the average by 5-10 times in comparison with the baseline data for the same subjects and the data of the control group.

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SIGNIFICANCE OF MUSCULAR ACTIVITY FOR THE PRESERVATION OF STABILITY OF AN ASTRONAUT'S MOTOR FUNCTIONS

A.V. Korobkov and B.A. Dushkov

ABSTRACT: The psychological and physiological effect of weightlessness, limited mobility and hypoxia are examined. The use of exercises as a means of prophylaxis of these effects is discussed.

The problem of motor function stability has great significance for the preservation of various aspects of an organism's life activity and the maintenance of a high work capacity for an astronaut in flight. Motor function stability is essentially connected with the developmental level and nature of a number of psychological, physiological and biochemical processes, and also with the morphological development of various organs and systems which, in turn, depends upon the character and level of the man's physiological preparation. /148

In some cases a high degree of physical preparedness insures an expansion of the possiblities for life under the condition of a change in the gas content of the air, temperature, natural radiation, etc. In other cases there is a broader compensation for possible negative changes arising under conditions of existence different from the terrestrial ones (weightlessness, etc.).

At the basis of deepening and preserving the connections between an organism and the immediate environment, which are achieved as a result of systematic and organized motor activity, lies the performance of a number of psychological functions, control of movements and metabolism, with the functions of breathing, of blood circulation, of excretion, of glands, of internal secretion, , etc.

We will not stop to analyze a man's physiological reactions to all factors of a space flight; we will only indicate a change in some characteristics of motor function in connection with conditions of weightlessness and hypodynamia.

Dietplein (1964) noted that upon completion of physical work (stretching a rubber shock absorber) at the time of Cooper's flight, the speed of restoration of pulse frequency to its original rate after the work was noticeably slower during the flight than under preflight conditions. This relatively slow restoration of pulse indicates the worsening of the general condition of the astronaut, inasmuch as the speed of restoration of the pulse rate is one of the basic indices of the level of physical training. Orthostatic hypotension also developed, with an increase in the pulse rate from 83 in a horizontal position to 123 while standing. Cooper's average arterial pressure after the flight was noticeably lower than before or during the flight; even 18 hours after the flight there were indications of orthostatic intolerance. In studying the data of astronaut Shirra's flight, the same author indicates that in the post-flight period, the pulse rate in a horizontal position was 56, arterial pressure 120/84 mm Hg. Upon transition to a vertical position, the pulse increased to 104, and arterial pressure lowered to 94/70. It is worthy of attention that these orthostatic hypotensive phenomena were retained for 18 hours after the flight. Shirra did not note any dizziness or other symptoms which could be attributed to the cardiovascular system when he moved to a vertical position in the post-flight period. 149

The appearance of orthostatic hypotension observed after these two flights is evidently the result of the action of unfavorable factors, in particular weightlessness. In the presence of gravity, the large veins of the lower extremities are subject to a pressure of around 100 mm Hg, due to the weight of the hydrostatic column of blood. In weightlessness and also while lying in bed, with immobilization or while staying in water, this hydrostatic pressure is practically absent. Vasomotor reflex mechanisms, which control the tone and maintain the return flow of blood to the heart, do not provide for successful control of vascular tone. Upon return to normal gravity, these reflexes cannot be recovered quickly without a certain period of readaptation to the forces of the gravitational field, and blood accumulates in the veins of the lower extremities.

According to Dietlein (1964), under the conditions of weightlessness the stress on the skeletomuscular system decreases noticeably. Forward progress of the body is facilitated, and the necessity for contraction of powerful muscles, which support the normal position of the body, is reduced significantly. Simultaneously, the stress and tension imparted to portions of the skeleton during muscle contractions lower, and the stress on the skeleton connected /150 with its function of supporting body weight is reduced. We must keep in mind that strict bed rest or immobilization leads to atrophy of the muscles and finally to extensive elimination of calcium in the urine, which is connected with the beginning of demineralization of the skeletal bones. The beginning of muscular and skeletal atrophy under the conditions of weightlessness can be expected after approximately 14 days, with a subsequent progressive increase if prophylactic measures or pharmacological remedies are not applied. Dietlein assumes that existing programs of isometric exercises can either forestall muscular (skeletal) atrophy or delay its development.

At the present time, one of the most widespread methods for the simulation of weightlessness under terrestrial conditions is the immersion of a man in water (Benson et al., 1962).

In studying the influence of a man's stay in water for various lengths of time, an actual lowering in the stability of the subject's cardiovascular system is noted in orthostatic tests (David, 1961). Grabiel and Clark et al. (1961), in studying the influence of immersion for various lengths of time, noted significant changes in the reaction of the cardiovascular system, muscular functions, movement coordination disturbances and the subject's ability to orient himself in space. It was noted that the G-load tolerance after a stay in water markedly worsened. In the first three days after beginning the experiments, a general water loss, polyurea, and an increase in the nitrogen eliminated in the urine was observed.

In the study of David (1961) explaining the influence of a reduction in motor activity on the ability to endure high forces, a lowering of muscular force and the ability to perform physical work and disturbances in motor function stability occurred. B.Ye. Graveline (1952) noted that as a result of a 7-day stay in water, the amount of work the subjects performed on a bicycle ergometer diminished. The work was accompanied by a more pronounced quickening of the pulse and of respiration, with a diminished pulse arterial pressure. An orthostatic test at the time of the experiment was accompanied by a more pronounced quickening of the pulse, a diminishing of the pulse arterial pressure, an increase on the EKG of *P*-wave /151
and by a merging of the *S* and *T* spikes. An investigation was carried out by professional divers who were completely immersed for 18 hours (with a respiratory mask) in a tub of water at a temperature of 34.4 to 35° (Bersom et al., 1962) with the aim of evaluating their functional status under simulated weightlessness. These authors noted that after an extended stay in water, the precision of movement diminished and many indices of movement coordination worsened. In the water, the subjects exerted much greater strength than was demanded by instruction.

Relying on a mathematical analysis of hemodynamics and considering the unusual circumstances of existence under conditions of lower gravitation, Moutzithropoulos (1963) indicated a number of disturbances which arose under conditions of weightlessness or lowered gravitation, the basic ones being muscular weakness and even degeneration of the muscles. The absence of the influence of the terrestrial force of gravity complicates a man's work on board a space vehicle to a significant degree, and can even lead to a great loss of work capacity. In addition, lowering of muscular tone can arise, as well as disturbances of coordination of the muscular activities. Nonetheless, it is possible to assume that man can adapt and carry out flight instruction without errors. The action of weightlessness on the cardiovascular system is expressed in a slight lowering of the arterial pressure and heartbeat rate with a periodic quickening of the pulse. Functions such as respiration, swallowing of food, defecation and urination are not disturbed. Thus, the human organism is able to endure exposure to weightlessness for a short period of time. The problem of the influence of an extended flight still remains open and awaits solution.

The influence of limited mobility on the human organism under various conditions of work and recreation activity was studied by a number of authors (A.U. Korobokov and colleagues, 1961). They investigated the action of extended (many day) relative adynamia under the conditions of sea travel and relative isolation. In the experiment they studied the influence of relative adynamia on the status of several motor functions under conditions of prolonged isolation. The authors discovered that under these conditions, changes which varied in degree arose both in the motor and in the autonomic functions. Under the influence of extended action of hypodynamia a sharp lowering of the functional capacities of the organism begins, according to such indices as muscular strength, endurance, and the ability to coordinate movements. The question of physical preparedness acquires an important practical significance under these conditions. Thus, weightlessness or a condition approximating it has a very substantial influence on a number of physiological reactions connected with motor functions which can determine the success of an entire space flight. With an increase in the duration of a flight, weightlessness has a great influence on the life activity and behavior of astronauts. At the present time it is possible to speak of two conditions of elevation of resistance of an organism to the action of unfavorable factors of the external environment: specific and nonspecific. By specific is meant the elevation of an organism's resistance achieved through the action of the same stimulus; for example, by overheating, by frequent stays in a high-temperature environment, to hypoxia by an insufficiency of oxygen in the air inhaled, etc. Development of resistance to any factor (for example, G-loading) through exposure to other stimuli (hypoxia) is an example of nonspecific elevation of stability. This phenomenon was noted a very long time ago and was widely used in the practice of water cures, physical exercises, cold sponge baths and air baths. /152

One of the means of nonspecific elevation of an organism's resistance to unfavorable factors is physical exercise, which simultaneously solves a number of problems enabling the improvement of motor and autonomic functions in the organism.

Many experimental investigations and observations have shown that goal-oriented physical training and resistance-building elevates the stability of the organism to unfavorable factors in the environment and to diseases (N.B. Lazarev, 1958; A.V. Korobkov, V.A. Shkurdova, N.N. Yakovlev, Ye.S. Yakovleva, 1962, and others).

Physical training increases resistance to hypoxia (N.N. Yakovlev, 1955; Ya.A. Egolinskiy and M.M. Bogorad, 1959), to the action of toxic substances (N.V. Shernykov, 1959, et al.) and to penetrating radiation. Physical exercises can raise the organism's resistance to temperature changes (N.A. Matyushkina, 1956, et al.). /153

In the process of muscular work, an improvement of neural regulation of the motor and autonomic functions occurs. In goal-oriented physical training in the muscular system, the chemistry of metabolic processes changes essentially, neural and humoral regulation are perfected, and the activity of many enzymatic systems increases. All of this permits the development of the protective characteristics of the organism, and elevates his resistance to a number of deleterious factors.

In connection with the characteristics of space flight, an important question arises as to the nature of physical exercises (extent and intensity) which can be recommended for flight and their influence on the organism's work capacity and nonspecific resistance.

In a special series of investigations carried out by A.V. Korobkov, D.A. Golovachen and V.A. Shkurdodo (1960), it was shown that it was characteristic of each of the so-called nonspecific activity activity factors to have its own definite spectrum of action of the various functions. For the various factors these spectra can overlap and amplify one another, which often leads to an undesired effect. The training conditions have just as much significance, as was shown by A.V. Korobkov et al. (1960), when training was carried out in a high-temperature environment. In addition, the capacity for motor work increased, but resistance to radiation fell lower than in the control, untrained groups.

Serious disorders in internal organ (renal adiposity, atrophy of thymal lymphatic tissues, gastric ulcer and pancreatic ulcer) can arise in the organism under extensive exhaustive training, and also /154
with constant great stress. Similar pathological changes in various organs and tissues can be produced by more short-term, but extremely intensive, physical and emotional strain.

All these factors indicate the necessity to undertake methods and means of physical and psychological training which would reflect flight specifications and would consider the characteristics of complex reorientation and changes in function of the supportive motor apparatus under the conditions and factors of flight.

It is possible to assume, evidently, that a system of preparatory training, developed with a special goal in mind and continued by physical exercises in flight and upon return to Earth, permits maintaining a high physical and intellectual work capacity. The system of physical preparation must prepare a man for prolonged space flight and insure the preservation in flight of especially important motor habits, physical and moral qualities and also resistance to unfavorable specific conditions of flight. With this goal in mind, the various means and methods of physical training must be isolated. An important factor in the maintenance of a high work capacity and health of an astronaut is a well-organized motor activity regimen during the time of the flight itself. The programs of physical exercises which are correctly distributed over the daily period appear to be supportive points.

Success in the application of physical exercises in flight depends on to what extent a number of conditions are observed. The first requirement consists in that physical exercises must correspond to the dynamics of physiological processes which take place in the human organism and enable the restructuring of daily rhythm as it applies to daily conditions of life in the ship. An astronaut's motor activity regimen must be adapted to these concrete characteristics of daily periodicity and changes in physiological function.

Another important requirement is that exercise programs correspond strictly to the characteristics of an astronaut's activity and /155 the changes in physiological mechanisms in flight with consideration of the basic typical periods of the astronaut's professional motor activity (tempo, degree of physical effort, strain of attention, coordination, structure, etc.).

In the physiology of labor and recreation, it has been shown that the adaptation of rhythm and activity tempo takes place better and more quickly with supportive exercises which are similar to the proposed work in tempo and rhythm (B.A. Dushkov, 1963). This is also confirmed by experimental work carried out under conditions approximating those of a space flight (isolation, limited mobility, hypokinesia, etc.). Thus, for example, an investigation of two different regimens (10 days each) of motor activity under conditions of limited mobility and isolation (A.D. Korobkov, 1961) demonstrated that a more rational program of physical exercises can increase resistance to the depressive action of the multiple factors of isolation. The authors also showed that various forms of applied physical exercise made possible more stable intellectual work capacity at various times of the day. Exercises are important factors for the elevation of emotional-volitional tone, ensuring great effectiveness of the restorative processes. The positive influence of systematic application of physical exercises leads to the elevation of intellectual work capacity and the improvement of the subject's general condition.

For the maintenance of the physical training of astronauts under the conditions of prolonged weightlessness in the limited area of the space ship, several authors (for example Aunan Wallace, 1964) recommended isometric exercises involving the pushing and pulling of immovable objects. The method is based on the premise that muscle develops more quickly if the efforts made do not lead to complete exhaustion. Muscular contraction lasting 6-8 seconds has the greatest effect. In the opinion of the author, during this period the muscle is in a condition of tension but its energy resources are not exhausted. Strength of muscular fibers is connected with the fact that the muscle does not pass through the restoration phase, which is necessary after exhausting exertion. Training according to this system must be gradual. In the first 2-3 weeks, the recommended exertion is half the maximum. Without a preparatory period, full exertion could lead to trauma. The duration of exertion must be carefully controlled. The system proved effective in the preparation of weight lifters, football players and other categories of athletes. As far as space flight is concerned, it remains unclear how much time must be alloted to the astronauts for the described exercises. Under usual conditions 10-15 minute daily training is considered sufficient. For the conditions of space flight, it is possible that up to an hour per day (10-12 periods of 5 minutes each) would be necessary. Analogous exercises cannot be included in the system of preflight preparation of astronauts. However, Aunan Wallace does not present sufficiently convincing experimental material supporting his views.

A number of authors studied the influence of physical training and work capacity under conditions of extended hypodynamia (V.V. Bazhanov, V.I. Chedinov, 1964; V.V. Bazhanov, V.A. Sergeyev, V.V. Mitin, 1965). The authors investigated a system of inertial and isometric exercises which was completed with a sharp stop at the end of the time of greatest exertion. Results of investigations show that application of physical training for prolonged limited mobility increased the maximum strength of the subjects by 3.3%, in addition, several functional indices were improved. For example, the ability to complete mental work with submaximal intensity grew by 5-7%, and the strength of the specific group of muscles, by 5-10%.

In two 15-day experiments, a study of the influence of various work and rest regimens on the functional status of the subjects also showed the positive influence of physical exercises for the maintenance of a high level of work capacity and lowering of fatigue.

In the first experiment a system of training of subjects was applied. The exercise program included various physical exercises of the pulling type, movements for strengthening of the muscles of the body, trunk, legs and arms, exercises for the relaxation and coordination of movement and also exercises with an expander*, weights and a bicycle ergometer. All the subjects noted a significant improvement in their general condition after the exercises. /157

As a rule, their work capacity increased, motor activity improved and the feeling of fatigue and sleepiness disappeared.

Inquiry and visual observations indicate that the rate and the tempo of exercises changes depending upon the days of exercises and the general condition of the subjects. They seem to become accustomed to the definite rate of completion of motor actions which was characteristic only for them. Such an acclimation and stabilization to a tempo can serve as a evaluation of the condition of the subject.

*Ed. note: Probably exercise springs or elastic straps. These are often termed "chest" expanders in this country.

During the first days in a hermetically sealed chamber, when asked "What tempo is best for carrying out the exercise program: slow, average or fast?", the subjects most often chose the average tempo. However, as far as completing the programs of physical exercises is concerned, in the questionnaire data there were statements of a desire to change the various tempos--slow, fast and average and their combinations. With a further completion of exercises there appeared individual differences in the tempo of movement.

In the period of adjustment to a new regimen of work and rest, especially in the first two days of the experiment, often the order was varied and the sequence of the repetition of individual exercises was stipulated in the experimental program, despite sufficient mastery of the program ahead of the experiment. Exercises were completed lazily, carelessly with disturbances in the amplitude and basic characteristics of movement.

On the 5-6th day, the same exercises were performed with great desire and interest. Fewer mistakes were made, the quality of completion improved and there appeared to be a desire to increase the exercise period for greater repetition of individual movements. At the end of the experiment a certain lowering of interest in the physical exercises was noted as a consequence of adaptation during the 15-day experiment to the program.

It is necessary to indicate the subjects' positive attitude to completion of exercises with the chest expander, weight and on the bicycle ergometer. /158

In the second 15-day experiment, the physical exercise program was constructed in accordance with specifications of chamber conditions: limited room for activities, altering the location of instruments, etc. For establishing a system, an order of physical exercises was planned which would set up a correct and regular distribution of individual exercises or groups of them in a definite pattern creating a more favorable reaction on the part of the organism to the applied exercises. In the normal regimen, an exercise program is included after periods of sleep and taking care of personal needs, and after the watch period.

Programs of "morning" hygienic calisthenics consisted of stretching exercises and of those involving individual muscle groups. A long stay in a chair (reclining chair) and forced static position of the body required consideration of the typical moments and phases of watch duty for the design and implementation of exercise programs during watch periods. At the time of caring for personal needs, a program was directed toward the maintenance of basic motor habits and physical qualities.

Such a comprehensive regimen of motor activity with a correct and regular distribution of physical exercise programs permitted the subject to maintain stability of strength and endurance of basic groups of muscles during his stay under conditions of limited motor activity in a chamber of small volume. A combination of various forms of physical exercises included in the usual regimen of work and rest were directed toward the perfection of a man's motor activity, and appeared to have a positive influence on the work capacity and the lowering of fatigue of the subjects and also facilitated maintaining general motor activity under the conditions of the chamber.

Thus physical exercises applied in the motor regimen can serve as an important moment both in the process of preparation for a prolonged space flight and for the preservation of a high capacity for work during the flight and the post-flight recovery period.

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INVESTIGATIONS OF HUMAN MOTOR FUNCTIONS UNDER THE CONDITIONS OF AN ALTERED DAILY REGIMEN

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ABSTRACT: Investigations of the effects of an altered daily regimen upon muscular strength and endurance are reported.

The question of the resistance of human motor functions to specific conditions acquires great significance in connection with the problem of extended space flights. A number of authors (Yu.V. Vanyushina et al., 1966; L.I. Kakurin et al., 1966, and others) showed the influence of unfavorable factors (hypodynamia, changed regimen of eating, etc.) on the neuromuscular apparatus. However, there remains the little-studied question of change in human motor functions during a prolonged stay in close quarters under the conditions of an altered daily rhythm. /159

We investigated the influence of an altered daily rhythm[1] (18-hour daily rhythm) on the function of the muscular apparatus. We applied a number of methods for defining the precision and resistance of the indices of simple motor reactions and muscular activity. In the 15-day experiment three subjects took part (Subject M., Subject I., Subject S.). /160

Measuring muscular strength and static endurance was carried out with the aid of a manual dynamometer of special construction by B.M. Abalakov (Central Scientific-Investigatory Institute of Physical Culture). Measurements were taken before and after the experiment and also on the 4th, 7th, 10th and 13th day, before the first and second watch and also after the watch. Measurements of strength and endurance of basic muscle groups were taken before and after experiments on a special test stand, which permitted particular muscle groups to be investigated in flexor and extensor movements of the forearm, the shoulder, the trunk, the hips and the lower legs.

Investigation of the muscle-joint system and the coordination of movements in small and large exertions were made with the aid of a dynamometer. Under the experimental conditions, it was necessary for the right hand to repeat small (1/10 of maximum) and large (1/2 of maximum) predetermined efforts. The actions had to be performed without looking at the indicated dynamometer.

[1]The experimental conditions are described in the article by A.A. Veslova, N.A. Gurovskiy et al. included in the collection of essays.

The habit of judging one's quantitative exertions was developed and intensified in preliminary experiments. On the same dynamometer, a study of the "sense of time" was carried out (on 3 and 10 seconds) which was developed before the experiment. There, the subject exerted a quantity (small or great) force with his right hand; with his left, he used a stop watch. During the development of small and large exertions, mistakes in reproduction of a given force for a given duration were evaluated.

In order to make a complete study of motor functions, a "stabilograph" developed in the Central Scientific Institute of Physical Culture was used to evaluate the ability to meter efforts precisely with redistributed pressure underfoot. The method is the following: /161 the subject stands on a stabilographic platform and takes a standard pose (usual standing). He must follow a "program" curve which had been plotted earlier on a moving paper tape of a recorder, and by redistributing the pressure on the rim of the stabilographic platform, control the pen of a recording galvanometer, producing maximum coincidence of his curve with that of the program.

For analysis the indices of disaccord were considered, expressed in arbitrary units, as well as the results of their statistical treatment. In order to evaluate the abilities and the alternation of activity of specific muscular groups, periods of voluntary tension and relaxation of the skeletal muscles (according to V.O. Fedorov) was used. The indices of latent times of tension (L.T.T.) and relaxation (L.T.R.), and also their relationship (L.T.T./L.T.R. index), was developed as a generally accepted method of mathematical statistics.

According to the data of the investigation of muscular strength and static endurance, muscle-joint sense and the duration of development of small and large isometric forces, sharp changes or weakening were not observed. However, it is possible to note essential fluctuations of muscular strength, muscular endurance of the hand, muscle-joint sense, "the sense of time" and the daily dynamics during the experiment. Especially large changes according to these indices were noted for subject M. At the end of the experiment his muscular strength dropped by 7 kg; results characterizing the muscle-joint sensitivity to a small effort worsened. For the same subject one must also note a significant fluctuation in the sense of time and the muscle-joint sense according to data obtained in the first and second watch and also each day of the experiment. Such changes in indices characterizing an adaptability on a subtle plane in the organism to /162 a definite regimen of life activity can be explained evidently by the fact that his daily periodicity was seriously disturbed, and the adaptation to a new change in sleep, waking and work had not yet taken place. For the two other subjects during the experiment there was noted a less pronounced shift in muscular strength and in data characterizing strength response and intervals of time. In comparison with the measurements taken before the experiment, during the 4th, 7th and 10th days, for subject I. there was a small increase in muscular endurance. It was characterized by a stable amount of from 25-30 seconds during the 4th, 7th, 10th and 13th day of the experiment.

For subject S. a significant lowering of muscular endurance was observed, which after the experiment diminished for the right hand from 35 to 17 seconds, and for the left from 42 to 12 seconds. In addition, the muscular endurance already by the 4th day of the experiment dropped in comparison with the original data by 7 seconds for the right hand. The sharp lowering of muscular endurance evidently indicates the lesser degree of training of this subject to similar type of experiments, as it was only the second time he had taken part in experiments while the two other subjects, M. and I., had been participants in many extended experiments in the chamber. The muscular endurance for subject S. in the first watch during the entire experiment (4, 7, 10, 13th days) was more than after the watch, which indicates signs of developing fatigue toward the end of the watch. For subjects I. and S. the "sense of time" and the muscle-joint sensitivity indices for small and large forces improved the longer they stayed in the hermetically sealed chamber in comparison with the first phase, which indicates a certain adaptation of the organism to the alternation of various periods of sleep, work and rest. Materials received by the method of program stabilography indicated that subjects I., M. and S. underwent the complex restructuring of daily rhythm differently. The initial and final values of the indices of error in the stabilogram demonstrate a pronounced improvement and the completion of the tests for subject I. and M. and a lack of any noticeable change for S. (Table 16).

TABLE 16. RESULTS OF ANALYSIS OF STABILOGRAM FOR SUBJECTS BEFORE AND AFTER THE EXPERIMENT. /163

No. of Attempts and Statistical Characteristics	I.		S.		M.	
	Before	After	Before	After	Before	After
1	673.5	398.0	420.0	469.0	754.0	558.0
2	460.0	494.5	486.0	474.5	634.0	494.5
3	435.5	440.0	508.0	499.5	520.0	456.0
4	517.5	395.0	501.5	336.5	518.5	464.0
5	360.5	421.5	375.5	406.5	574.0	410.5
$M \pm m$	489.5±52.45	429.8±18.14	458.1±25.98	437.2±29.47	600.1±43.93	476.6±24.39
$\sigma \pm m$	117.3±37.09	40.56±12.82	58.1±18.37	65.9±20.84	98.22±31.06	54.54±17.25
v,%	±24	±9	±13	±15	±16	±11
P,%	±11	±4	± 6	± 7	± 7	± 5
t		1.08	0.53			2.46

In Table 16 the differences in statistical characteristics are shown. Thus, for subject S. the criterion of reliability of differences is 0.53, for I. and M. 1.08 and 2.46, respectively. Moreover, indices of fluctuations of the sign show the difference in the subject's reactions to the action of the factor: S., ±15 and ±7% against ±13 and ±6%; subject I., ±9 and ±4% against ±24 and ±11%; for M., ±11 and ±5% against ±16 and ±7%, respectively (see Table 16). It is possible to assume (on the basis of control experiments) that for subject S., as opposed to I. and M., a natural scientific performance of tests was "blocked" by complex experimental conditions and a radical change in the daily rhythm of life activity.

On the basis of the total analytical data, it is possible to judge that stability of the maintenance of position was practically unchanged, and subject M. was even more resistant to the effect of this factor (according to the given tests). Results of electromyographic analysis of the ability for maximally quick alternation

TABLE 17. LATENT TIME OF TENSION AND RELAXATION FOR SUBJECT M. IN THE SECOND EXPERIMENT. /164

Muscles		LTT_{max} millisec		LTR_{max} millisec		$\frac{LTT_{max}}{LTR_{max}}$		LTT_{min} millisec		LTR_{min} millisec		$\frac{LTT_{min}}{LTR_{min}}$	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Sural	right	420	380	440	210	0,955	1,810	240	100	190	130	1,263	0,769
	left	420	420	380	300	1,105	1,400	280	240	210	60	1,333	4,000
Tibial	right	340	360	410	360	0,829	1,000	220	180	390	200	0,564	0,900
	left	500	340	480	420	1,042	0,810	210	180	380	200	0,553	0,900
Right Hip	right	510	240	480	230	1,063	1,043	230	160	460	140	0,500	1,143
	left	300	480	440	370	0,682	1,297	160	380	320	180	0,500	2,111
Biceps of the Hip	right	480	490	560	240	0,857	2,042	180	220	300	220	0,600	1,000
	left	380	520	440	510	0,864	1,020	260	120	220	220	1,182	0,545
Biceps of the Shoulder	left	350	320	310	470	1,129	0,681	300	180	280	290	1,071	0,621

TABLE 18. RESULTS OF STATISTICAL DEVELOPMENT OF INDICES OF LATENT TIME FOR SUBJECT M. BEFORE AND AFTER EXPERIMENT (VOLUNTARY TENSION AND RELAXATION OF MUSCLES).

No. of Attempts	Index	$M \pm m$		$\sigma \pm m$		v, %		P, %		
		Before	After	Before	After	Bef.	Aft.	Bef.	Aft.	
1	LTT_{max}	411±25,1	394±31,1	75,4±17,8	93,4±22,0	±18	±24	± 6	± 8	0,42
2	LTR_{min}	438±22,7	346±35,6	68,2±16,1	106,7±25,1	±16	±31	± 5	±10	2,18
3	$\frac{LTT_{max}}{LTR_{max}}$	0,947±0,051	1,234±0,151	0,152±0,036	0,452±0,106	±16	±37	± 5	±12	1,81
4	LTT_{nin}	231±15,3	196±26,8	45,8±10,8	80,5±19,0	±20	±41	± 7	±14	1,13
5	LTR_{min}	306±30,0	182±22,1	90,0±21,2	66,4±15,7	±33	±37	±10	±12	3,33
6	$\frac{LTT_{min}}{LTR_{min}}$	0,841±0,120	1,332±0,367	0,360±0,085	1,101±0,259	±43	±83	±14	±28	1,27

between muscular tension and muscular relaxation are presented in Tables 17 and 18. /165

A tendency toward the lowering of indices of latent time (LT) after the experiment is apparent.

One of the more probable causes of such a leveling off of changes of mean LT values for various muscles is evidently the multidirectedness of these changes for muscles of anatomical antagonists and contralateral muscles, noted for subject M. after the experiment. This is apparent after comparison of the values of LTT maximum of the right sural and tibial muscles, of the right rectus and bicep muscles of this hip, of the right and left tibialis muscles of the right and left rectus of the hip; LTT minimum of the rectus muscle of the left rectus and bicep muscles of the hip, of the right and left bicep muscles of the hip (Table 17).

It is necessary to note the primary increase in the LTT/LTR index, evidencing, according to V.L. Fedorov, the improvement of the balance between the excitory and inhibitory components. The combined multidirected changes in this index for muscles again shows the cross character of the phenomena of an altered regimen (LTT_{max}/LTR_{max} for right and left biceps, for left sural and biceps muscles; LTT_{min} and /166 LTR_{min} for right and left sural of right sural and bicep muscles, for right and left bicep muscles of the thigh, for left rectus and bicep muscles of the thigh).

Attention is drawn to the elevation of LTR indices and a decrease in the LTT/LTR index (for both minimum and maximum values) of the biceps of the left arm, the only muscles of the upper extremities whose change in the temporal characteristics EMG can be registered (Table 18). Greater fluctuation of indices characterizing muscular endurance are observed for subject S. Thus for 8 tests of separate muscular groups (flexor and extensor of the trunk, the hip, the forearm and the calf and flexor of the shoulders) in 5 instances a lowering of endurance occurred, and in 3 instances there were no changes. For the two other subjects, in 5 out of 8 instances there was an increase and in 2 a decrease, and once the indices remained unchanged. A lowering of endurance of the basic muscle group for subject S. is explained, evidently, by the fact that he was not as trained as the other subjects to these difficult experiments. No less significant in the lowering of muscular endurance for subject S. was the fact that he, in contrast to the other subjects, did not always complete the program of physical exercises fully, especially those movements which were calculated for this quality.

Thus fluctuation in muscular strength, endurance of muscle-joint sensitivity and temporal intervals in the process of experiment could be explained by the complex restructuring of daily rhythm of physical functions. In this restructuring the distribution of sleep in the day preceding the investigation was of great significance.

Comparison of the characteristics of cluctuations of indices of muscular tension and relaxation before and after the experiment permits one to note a significant growth of variability of all indices under the influence of unusual circumstances of the experiment. The fact that the subjects' regimen of life activity was significantly altered, both in duration and in distribution of hours of work /167 and rest (18-hour daily rhythm), had a great significance on the changes in these indices.

At the same time, the regimen of work and rest and various alterations in sleep and activity did not lead, by the end of the experiment, to an essential change in the strength and endurance of the basic muscle group, with the exception of several separate muscle groups, which indicates evidently that the subjects' motor activity was correctly organized. The organism's adaptation to such an alteration of work and activity periods, in which the daily rhythm is sharply altered (according to indices of precision and resistance of temporal-strength responses) takes place slowly (on the 10th and 13th day). In addition, the usual periodicity of changes in physiological indices is established.

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